MEDICAL ELECTRICITY:

A PRACTICAL TREATISE

ON THE

APPLICATIONS OF ELECTRICITY TO MEDICINE AND SURGERY.

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TO

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IN THE

UNIVERSITY OF MARYLAND;

SCHOLAR, AUTHOR, PRACTITIONER,

MY TEACHER AND MY FRIEND.

PREFACE TO THE SECOND EDITION.

As a considerable edition of this treatise was exhausted within a year, and the demand continuing unabated, I feel that I did not misconceive the need of the time for a practical work on Medical Electricity. My purpose was to prepare a work from the practitioner's, rather than the merely scientific, standpoint. In the present edition the same conception of the subject continues paramount; and in that spirit, I have made many additions and improvements to render the work more useful to those for whom it is intended. At the same time, in response to what seems to me an increasing desire for scientific treatment, I have developed more fully the modern methods of ascertaining and expressing current strength, tension, resistances, etc. I have, also, entered more fully into the polar method, and into the action and uses of the magnet. Notwithstanding an increase in the number of lines to the page, and the condensation of the matter new and old, the work has been enlarged by the addition of thirty pages. Thus improved, I may be permitted to hope that the new edition will continue to enjoy the favor so largely bestowed on the first.

ROBERTS BARTHOLOW.

PHILADELPHIA, 1509 Walnut Street.

PREFACE TO THE FIRST EDITION.

In my annual course of Lectures on Materia Medica and Therapeutics, I have discussed, more or less fully, the subject of electricity as a therapeutic agent. It happened in this way that my attention was called to the need of a suitable text-book. That there are excellent works on medical electricity is undeniable; but some of them are too voluminous, others too scientific, and not a few wanting both in fulness and in accuracy. I have attempted in the preparation of this work to avoid these errors; to prepare one so simple in statement, that a student without previous acquaintance with the subject may readily master the essentials; so complete as to embrace the whole subject of medical electricity, and so condensed as to be contained in a moderate compass. I have endeavored to keep constantly in view the needs of the two classes for whom the work is prepared—students and practitioners. I have assumed an entire unacquaintance with the elements of the subject as the point of departure—for I am addressing those who have either failed to acquire this preliminary knowledge, or having acquired it, find that after the lapse of years it has become misty and confused.

In the account of electrical phenomena, I have adhered to the modes of expression with which the medical electrical text-books have made us familiar. The time has not come, it seems to me, to adopt the terms and explanations now employed by practical electricians: it is a transition period in which both the old and the new should have a measure of recognition. I have, accordingly, followed the usual course in the account of electrical principles and instruments, introducing also the new terms—the units—by which the electro-motive force, quantity, capacity, and resistance are expressed. Electricity as applied to practical arts—to lighting, heating, telegraphy, and mechanical work generally—demands different treatment, especially as

respects the means and methods of exact measurement, from that required in the presentation of its medical uses. Although it is true that exacter methods of stating current strength, resistances, etc., are desirable in the medical applications of electricity, we are not yet in a position to avail us of the results achieved in the applied science, for the human body is an altogether more uncertain quantity than a copper wire of given length and sectional area. Furthermore, a proper statement of the various questions in the electrical science of to-day, requires the use of the higher algebra and the calculus—an amount of mathematical knowledge not universally possessed by medical students and practitioners. I have, however, entered somewhat into the consideration of the polar method, especially as developed by Erb and Brenner, and have described the mode in which the reactions are now expressed. An entirely novel subject is the adaptation of the Toepler-Holtz electrical machine, by simply connecting the interior and outer coating of the condensers, for the production of nerve and muscle reactions just like those of the primary faradic current. I know of no publication in which this novel fact has been stated.[1] It accordingly opens up for the first time an important field for future investigation and research.

This book, then, must be regarded as the exposition of electricity for remedial purposes, made by a medical practitioner for the use of other medical practitioners. No claim is made on the ground of pure science. It is believed, however, that the work makes an adequate presentation of the subject, regarding electricity as a remedial agent —as one of the means employed for the treatment and cure of disease.

ROBERTS BARTHOLOW.

PHILADELPHIA,
1509 Walnut Street, March, 1881.

[1] As this work is going through the press, my attention is called to a paper by Dr. W. J. Morton in the New York Medical Record for April 9.

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A TREATISE

ON

MEDICAL ELECTRICITY.

INTRODUCTION.

MODES OF THE FORCE.

ELECTRICITY is one of the physical forces—a mode of manifestation of energy, kinetic and potential—and is convertible into or is correlated with the other modes of force. It is manifested in several forms; as—

MAGNETISM.
STATIC ELECTRICITY:
  Vitreous,
  Resinous.
DYNAMIC ELECTRICITY:
  Galvanism,
  Faradism:
    Electro-magnetism,
    Magneto-electricity.
THERMO-ELECTRICITY.

Magnetism differs from the other modes of electrical force in that the energy of the excited body is always present. The pieces of magnetic iron ore, or of steel in which the magnetic property has been induced, are always in a condition to exhibit their special powers;

i. e., suspended and free to move, always assuming a uniform direction, or attracting certain bodies in their neighborhood. Static electricity is developed from a material —glass or resin—which is entirely quiescent until excited by friction. Galvanism is produced by chemical action or by contact which causes electrical separation, and faradism is the result of induction by galvanism. When friction or chemical action ceases, the resulting phenomena subside.

Medical electricity is the application of the science of electricity to the requirements of medical practice, and is concerned with all of these modes or manifestations of electrical energy.

There are certain terms now employed in giving mathematical expression to the facts of physical science, and some knowledge of them is therefore necessary in the study of electricity.

Matter and *force* are terms in frequent use. From the point of view of physics, matter is a something by and through which the forces act. Force is defined to be that which can change any body's state of rest or motion. The unit of force is called a *dyne.*

The unit of mass is a cubic centimetre of distilled water at 4° Cent. This mass is the *gramme*, and on it is based the decimal system.

Work is defined as overcoming resistance through space. When a weight is raised, work is done in overcoming the force of gravity through the space over which the weight is moved. The English unit of work is the foot-pound—that is, the work done in raising one pound one foot in height. The Continental unit of work, called the *Erg*, is the work done in moving a gramme, through the space of a centimetre, against a unit of acceleration.

Energy is the capacity for doing work, and may be

kinetic, when the body employed is in actual motion, or it may be *potential*, when it has the power to do work, or is in a condition that work may be recovered from it. Thus, when a spring is bent, or weight raised, and is in a position to act, potential energy is acquired by the work done in bending the spring or in raising the weight. Potential becomes actual or kinetic energy when the spring or weight is released to move some other body, or to do work of some kind.

Difference of potential between any two points is the work done in carrying a unit of mass from one point to the other. *Zero* potential is the point chosen as a standard of reference. Any place which requires work to be done to bring the unit of mass from the zero point to it will have *positive potential*, and any place which requires work to be done to bring the unit of mass from it to the zero point has *negative potential.*

PART I.

ELECTRO-PHYSICS.

CHAPTER I.

MAGNETISM.

The term "magnet" was originally applied to certain iron ores possessing peculiar properties, and which were found near the ancient city of Magnesia, in Asia Minor. In one respect this native ore differed from all others: it had the power of attracting to itself other small particles of iron. It was subsequently discovered that the property possessed by some natural iron ores could be communicated, under certain conditions, to other pieces of iron; whence the distinction into *natural* and *artificial* magnets. The natural magnet is also called *lode-stone*, or, more properly, *lead-stone*, because of the power it possesses of drawing, or leading to motion, certain substances subjected to its influence. If a permanent magnet be made to approach a bar of soft iron, suspended at its centre and free to move, the bar is attracted and moves toward either end of the magnet. If now a bar-magnet is substituted for the soft iron, and suspended to move freely, when another permanent magnet is made to approach, it is found that, whilst one extremity of each is attracted, the other extremities are not attracted—are, on the contrary, repelled, and they cannot be made to approximate to each

other. Moreover, we observe that the suspended magnet left to itself invariably assumes a certain position. If disturbed, after a period of oscillations, it finally settles to rest in the one position—one extremity pointing to the north, the other to the south. Further investigations demonstrate that the peculiar properties of the magnet reside only in the extremities, and that they disappear at the centre, which is hence known as the *neutral point* or *magnetic equator*, etc. These extremities of the magnet are termed *poles*, and the property exhibited by them is called *polarity* (Fig. 1). That extremity of the magnet which points to the north is called the *north pole* —or the *marked* extremity, because it always contains a mark to designate it; the other end is called the *south pole.* If we bring the north pole of one permanent magnet into the neighborhood of the south pole of another permanent magnet, they immediately attract each other and strongly adhere, so that some force is required to separate them. On the other hand, if we approximate the north or the south poles of the two magnets, they manifest a mutual repugnance and fly from each other. Hence the law: *Like poles repel, unlike poles attract.*

FIG. 1.

A permanent magnet.

Not all bodies are affected by a magnet in their neighborhood. Some are attracted; others are repelled; the former were entitled by Faraday *magnetic*—the latter *diamagnetic.* No substance is so strongly affected by a magnet as iron. The following is a list of the more important of the two groups:—

Magnetic.	Diamagnetic.
Iron,	Bismuth,
Nickel,	Antimony,
Cobalt,	Zinc,
Manganese,	Tin,
Platinum,	Mercury,
Osmium,	Lead,
Palladium, etc.	Silver,
	Copper,
	Gold,
	Arsenic, etc.

The substances in the list of magnetic bodies are not affected to the same extent, yet they are all attracted in the same way. If a needle or small iron bar is suspended between the poles of a powerful permanent magnet, so made that the north and south poles are exactly opposite each other, it assumes a position in a plane parallel to a line drawn from one pole to the other—an axial position. Whence we deduce the law: *A magnetic body suspended between the poles of a magnet assumes an axial position.*

If a diamagnetic substance—a piece of bismuth, for example—be suspended in the same way between the poles of a permanent magnet, it takes a position not axial, but at a right angle to axial—an equatorial position. Whence we deduce the law: *A diamagnetic substance suspended between the poles of a magnet assumes an equatorial position.*

Very different results are obtained when the body suspended between the poles of the magnet is at the same time immersed in a magnetic liquid instead of air. This point is well illustrated by suspending mica, a magnetic substance, in a solution of protochloride of iron, which is more magnetic. Under these circumstances the mica will not follow the same law as when suspended

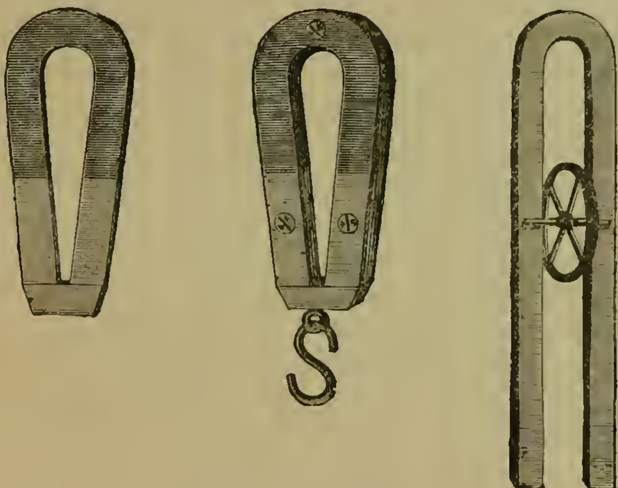
free in the air, and will instead assume an equatorial position. As the same results follow the same mode of treatment of other magnetic substances, we deduce the following law: *A magnetic substance suspended in a fluid more magnetic than itself will assume the position of a diamagnetic substance.* It is found that the converse is true, also—whence the law: *A diamagnetic substance suspended in a liquid more diamagnetic than itself will assume the position of a magnetic substance.*

It has been already pointed out that like poles repel and unlike poles attract. The influence of one magnet on another is also exhibited before they are actually in contact—even when a considerable space intervenes—but it is the more powerful the nearer they approximate to each other. This influence is expressed by this law: *The magnetic force is exerted inversely as the square of the distance.* When a permanent magnet is made to approach a bar of soft iron, the latter is attracted, because the opposite polarity is diverted to that extremity of the iron nearest the magnet. In this fact we have an exhibition of the phenomena of induction. Magnetism is a force existing in the bodies capable of its manifestations, under ordinary circumstances in a quiescent state. When the magnet is brought near to the bar of soft iron, the neutral magnetic condition of the iron is disturbed, and it assumes a polar state, north polarity magnetism accumulating at one extremity, and south polarity magnetism at the other. When the permanent magnet is withdrawn, these evidences of polarity cease, and the magnetism in the bar of soft iron resumes its neutral or unexcited condition. By the approach of the north or marked pole of the magnet, the opposite magnetism (or south) is *induced* at the extremity of the bar nearest the magnet. Similar phenomena occur in static electricity—

for example, when the excited electric approaches the suspended pith-ball. The production of two instantaneous currents in a coil of fine wire, about the conjunctive wire of the galvanic battery is another example of the principle of induction.

When a permanent magnet is broken into two pieces, each is found to possess north and south polarity; and if these two pieces are broken into others, each remnant is found to be a complete magnet. The subdivision may

FIG. 2.



Forms of horseshoe magnets.

be carried on still further with the same effect. This result is explained by supposing that each separate molecule of iron is endowed with the two magnetisms—with north and south polarity.

Magnets are made in the form of a bar, or of a needle, and of a horseshoe, the magnetic property being the same in either case (Fig. 2). In the preparation of a magnet the hardest steel is used. It ought to be so hard as not to be attacked by a good file. Steel is employed

for this purpose, and the hardest steel, because it possesses in a higher degree than ordinary iron the coercitive force—or the power to retain the magnetic property after it has been imparted to it. In the process of magnetizing a steel bar, the single or double touch may be employed. By the single touch, over that extremity which is intended to have north polarity, the south pole of a magnet is rubbed, beginning at the centre of the bar and stroking it outwardly, and coming back to the point of starting, through the air. The other extremity of the steel bar is treated in the same way with the north pole of the magnet. The double touch consists in applying two magnets, at an angle of 15° to 20° with the bar, beginning at the centre and stroking both extremities simultaneously. Certain precautions are necessary to preserve the activity of magnets. The poles, both of the straight and horseshoe form, should be connected by a bar of soft iron. Notwithstanding steel possesses in a high degree the coercitive force, the magnetic property may be easily destroyed. A blow, scratching the surface, rubbing with any hard substance, especially heating the magnet, injure its magnetic effect. It is injurious to lay the magnet on iron.

When a magnet is suspended or balanced on a pivot and free to move in any direction, it assumes, as has been stated, the position of north and south polarity (Fig. 1). When a magnetic body is suspended between the poles of a permanent magnet, it assumes an axial position. The earth is a great magnet, having its southern pole in the neighborhood of the geographical north pole; consequently, the north pole of the magnet is attracted toward the north—unlike poles attract. It is this remarkable property which renders the needle of the compass so important to mariners.

The needle does not always point due north. The angle which the north pole of the needle makes with a horizontal plane is called the "Dip" or "Inclination," and the angle which it makes with a vertical plane due north from the centre of the needle is called the "Declination." At the equator the needle is nearly horizontal, but as either pole of the earth is approached, it dips until at certain points it stands vertical. The declination of the needle from 1580 to 1657 was easterly in London, and from 1657 to 1815 was westerly, and since the last-mentioned date has been going easterly again toward the astronomical meridian. From the time of the discovery of the inclination of the needle up to 1723 the inclination increased; from that time to the present it has decreased. There seems to be a decennial period in the more considerable disturbances of the declination, and are apparently determined by the sun spots. There are oscillations diurnal, lunar, etc.

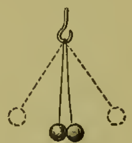
CHAPTER II.

STATIC ELECTRICITY.

Static, *frictional*, and *Franklinic* are the terms applied to this force. It is static, because the electricity is restrained in a condition of high tension; it is frictional, because developed by friction of certain substances, as glass and resin; and it is Franklinic, because Franklin demonstrated the identity of frictional with terrestrial electricity. The phenomena of static electricity are illustrated by simple means. If a glass rod is rubbed with a silk handkerchief, it is found to possess a new property.

That portion of the rod subjected to friction, if approached near a pith-ball suspended by a silk thread, attracts it, and after a short time in contact with the rod the ball is repelled. The friction develops electricity, the particles of which are self-repellant, since as soon as the pith-ball is charged it is continually repelled by the glass rod. This is called *vitreous* electricity, because obtained by the friction of glass. If now a piece of resin be rubbed with flannel, and brought near to the charged pith-ball, the latter will be at once attracted. After a time becoming charged with electricity from the resin, the pith-ball will be repelled, and whenever approached by the excited resin so long as it is charged by its electricity, repulsion will occur. We learn from this experiment that there is another form of electricity—the *resinous*, and that the particles of this are also self-repellant. If we reverse this experiment, and charge the pith-ball first with resinous electricity, we find that the ball is presently repelled, and that when in this condition, an excited glass rod is brought near it, the ball is at once attracted. It is clear, therefore, that the two electricities attract. From these observations we deduce the law: *Unlike electricities attract, like electricities repel* (Fig. 3).

FIG. 3.



Unlike electricities attract—like, repel.

According to the theory of Dufay, which is now generally held, there are two electrical fluids—the positive and the negative, or vitreous and resinous. These are generally distributed, mixed together, neutralizing each other, and perfectly quiescent, when so united. By certain

processes—friction, chemical action, motion, heat, etc.—a separation of the two electricities takes place, but there must be present just as much of the one as of the other. In rubbing the glass rod, the glass is excited positively, but the silk is excited in the same proportion, by negative electricity. These two forms of electricity are called respectively "positive" and "negative," and the signs + and — are used to designate them, the + sign being arbitrarily applied to vitreous electricity.

With regard to electrical action bodies are divided into two great groups, *conductors* and *insulators*. They may be arranged as follows:—

Conductors.	Insulators.
Metals,	Caoutchouc,
Charcoal,	Silk,
Graphite,	Glass,
Acids,	Wax,
Water, etc.	Sulphur,
	Resins,
	Shellac, etc.

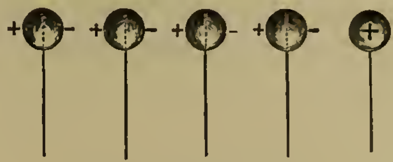
This sharp division into two groups is not always possible. In some instances, conductors of the least perfect kind become insulators; and poor insulators become tolerable conductors. The very best conductor offers some resistance to the passage of the current. Circumstances affect the position of these bodies. Dry air is a non-conductor, but if moisture is present it becomes a conductor. Glass is a non-conductor in the ordinary state, but when heated to redness, becomes a good conductor. A conductor is said to be *insulated* when mounted on some non-conductor or insulator. For example, a brass rod mounted on glass or caoutchouc is insulated. Without insulators, electricity could not be collected to exhibit the various phenomena of which this force is capable.

Electricity is not only transmitted by conduction, but it operates through the intervening molecules of air, by induction. Thus, if an excited glass rod is brought near to the gold-leaf electrometer, the leaves diverge. There is no conduction; the rod is not in contact with the brass knob of the electrometer, but the gold leaves separate as soon as the rod approaches, so that an influence of some kind is exerted through the air. When the excited glass rod approaches suspended pith-balls, they move towards the rod, for, on that side of the balls nearest the rod, the opposite or resinous electricity accumulates, whilst the vitreous flows to the other side. In other words, the excited glass rod *induces* the opposite, or negative, or resinous electricity on the side of the pith-balls nearest it. As in accordance with the law, unlike electricities attract, the pith-balls fly and attach themselves to the rod, until charged with vitreous electricity, when they are repelled.

Electricity accumulates upon the surface of bodies, and not in their interior. This fact is demonstrated by the following experiment: A solid sphere of brass, resting on a glass stand, is covered by two accurately fitting hemispheres of brass. Putting these hemispheres in position on the globe, they are charged with electricity. On removing the hemispheres, they are found to contain the whole charge, whilst the globe itself presents no evidence of the presence of electricity, showing that the electricity only diffuses itself on the surface. The form of the body receiving a charge greatly influences the distribution of the electricity. If a sphere be charged with positive electricity, and then be made to approach another sphere not charged, the neutral electricity of the latter is decomposed, negative electricity accumulates on the side nearest the excited sphere, and positive on the other side (Fig. 4). If, instead of a sphere, a cylinder be charged, and brought

near an unexcited cylinder, the electricity accumulates at the extremities, and the phenomena of polarity are exhibited.

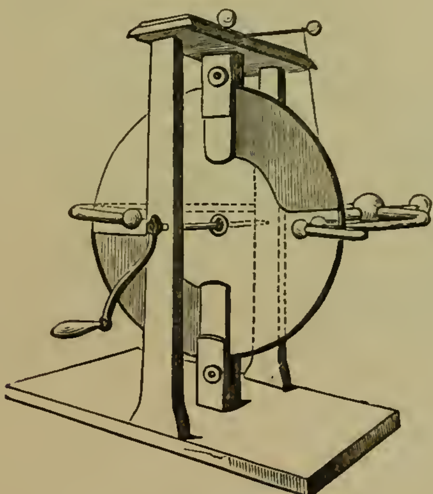
FIG. 4.



Electrical induction.

Certain substances without having the power to conduct electricity allow it to pass through them—in other

FIG. 5.



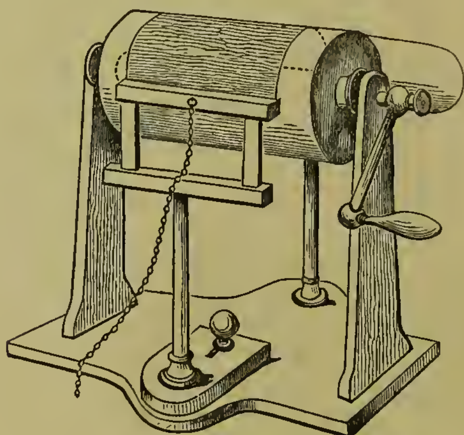
A plate-glass electrical machine.

words, they are transparent to electricity, as glass is to light. Such substances are said to be *dialectric.* If electricity be excited on one side of a plate of glass, the other side will exhibit electrical phenomena.

To obtain a large quantity of electricity, other means

than friction of glass rods or sticks of resin become necessary. Two kinds of electrical machines are used —the cylinder and plate glass (Fig. 5). The glass is subjected to friction by rubbers, and the electricity is collected by brass points and conveyed to a reservoir—the prime conductor (Fig. 6). The rubber becomes

FIG. 6.

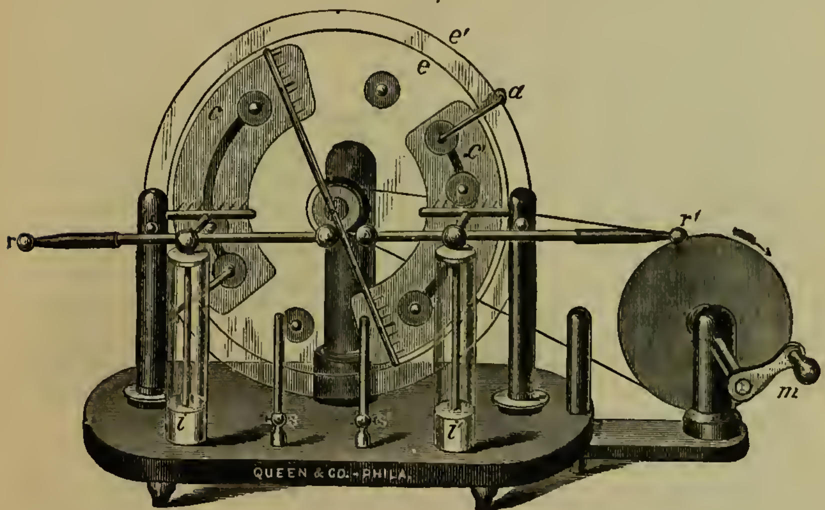


A cylinder electrical machine.

negatively and the glass positively electrified. In the Holtz machine (Fig. 7), the principle of induction is utilized. This machine consists of two circular upright glass or hard rubber plates placed very near each other, without touching, one arranged to revolve, whilst the other is fixed. The fixed plate has a central orifice, through which the axis of the other plate passes, and has on its outer surface some oblong pieces of parchment paper. In front of the revolving plate is a brass rod, containing at each extremity some projecting points or combs, and is fastened at the centre by a pivot. At the border of the fixed plate there are metallic combs, fastened on by rubber rods. There are two condensers

(Leyden jars), connected in their interior by brass rods, which communicate with the discharging rods; and their exterior coating is connected by a brass rod passing under the wooden base. The fixed glass plate of the original Holtz machine had windows, through which paper points projected against the revolving plate. In the Toepler-Holtz, these windows are dispensed with, and soft wire brushes are so adjusted in front, as to rub against brass knobs fixed in the revolving plate. To

FIG. 7.



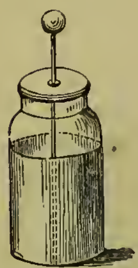
The Toepler-Holtz electrical machine.

start this machine, it is necessary, only, to place the discharging rods in apposition, and cause the revolving plate to move. When the current passes, the discharging rods are separated, and a stream of sparks flows from one to the other.

For the purpose of storing up the electricity, a Leyden jar is employed—so named from the city where it was first made. This jar is coated with zinc-foil, both

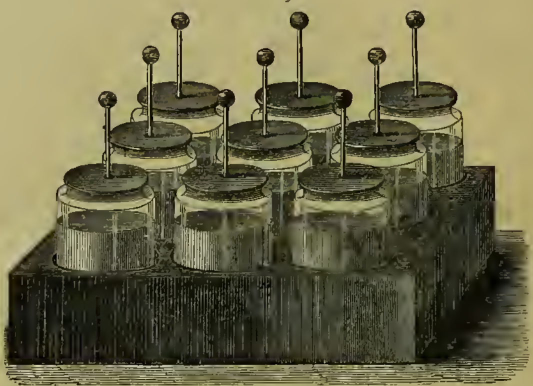
inside and outside, up to within one-fourth of its height (Fig. 8). As the glass is a dialectric, whilst the interior receives positive electricity from the prime conductor, the exterior becomes charged with negative. By connecting a number of these jars, a battery is made in which a very large quantity of electricity may be stored up (Fig. 9). In forming a battery of Leyden jars, the exteriors of the jars communicate with each other and with the earth, whilst the interior of each, also, communicates through the metallic rod and knob

FIG. 8.



A Leyden jar.

FIG. 9.



A battery of Leyden jars.

with each other, and with the prime conductor of an electrical machine. The electricity received by a Leyden jar is condensed in contact with the tinfoil, and is in a state of high tension. Discharge is effected with a loud report, when the interior and exterior are brought into communication by means of a discharging rod—a curved brass rod terminating in knobs and provided with insulated handles. A more or less vivid spark accompanies the discharge, made up of minute particles of brass and the air in an incandescent state. This discharge consists in the union of the positive (+) elec-

tricity within, and the negative (—) electricity on the outside of the jar. The addition of + and — in equal quantity, produces zero in algebra, and an equilibrium in electricity. If the charge of the jar—which is the quantity of electricity in it—exceeds its capacity, there will take place finally a spontaneous combination of the plus and minus electricities. The intensity of electrification at any point of a body or surface is called the *electric density* at that point. Now, the force with which electricity is moved to escape from any point or surface, increases with the density.

Difference of potential is said to exist whenever electricity is about to move, or does move, from one point to another, and that place has *higher potential* from which electricity moves, and that place *lower potential* to which electricity goes. The *difference of potential between two points* signifies the amount of work necessary to move a unit of electricity from one point to the other, against the direction it tends to go.

If two conductors, having different potentials, be connected by another conductor, electricity will move from the higher to the lower potential, until they are equal. If the difference of potential is maintained by the expenditure of work, the flow may continue so long as the work is done. As regards statical electricity, all parts of a conductor of the same material are always at the same potential, since when a difference of potential occurs, the return to the same potential is effected in the minutest fraction of a second.

CHAPTER III.

DYNAMICAL ELECTRICITY.

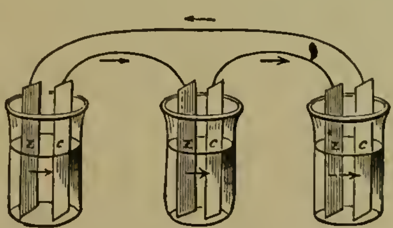
The original observation of Galvani, which led to the discovery of galvanism, may be readily repeated as follows: A frog is rendered insensible by a blow on the head, and is then divided through the middle of the body with a pair of stout shears. As quickly as possible, the intestines are removed, the skin stripped off, and the lumbar nerves dissected out. The preparation thus made is laid on a glass plate, and under the nerves is placed a strip of zinc. Now, on touching the lumbar nerves and the zinc with a copper wire, brisk contractions of the thigh muscles immediately ensue. This demonstration was made by Galvani in 1790, and from it has proceeded the whole science of *galvanism*. As Volta was, next to Galvani, the most important of the early investigators, his name is also rightfully honored by denominating this force *Voltaic electricity*.

The simplest mode of exhibiting the phenomena of galvanism, is to plunge the dissimilar metals—copper and zinc—into diluted sulphuric acid. This constitutes a *galvanic combination*, or *couplet*, or *element*. When ordinary commercial zinc is put into the acid, chemical action at once begins; the acid acts on the metal with great energy, and in a short time effects its solution. But the galvanic activity is by no means equal to the chemical. Owing to the impurities in commercial zinc, each strip immersed in the acid may be supposed to consist in a great number of minute galvanic combinations, between which complete circuits are formed.

Hence, whilst the action is violent, no "current" proper is produced. This serious objection to the use of commercial zinc in galvanic combinations, has been entirely obviated by a fortunate discovery. It has been found that if ordinary commercial zinc is amalgamated, it is no longer acted on by the acid, except when the circuit is complete, and the secondary currents, between the impurities in the metal and the particles of zinc, are entirely prevented. The process of amalgamation consists in immersing the zinc in diluted sulphuric acid, and then rubbing the clean surface with some mercury. Immediately the zinc assumes a silvery brightness, and its surface becomes homogeneous.

To develop a galvanic current, there must be dissimilar metals. Galvani supposed that the contact of dissimilar metals was alone necessary, but it was soon discovered that one of the metals must be acted on. That dissimilar metals are essential, is undoubted, for if two plates of zinc, or two plates of copper are employed, there is no

FIG. 10.



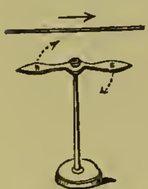
Galvanic couplets and conjunctive wire.

result—no current is produced. One of the plates must be acted on, and becomes the *generating plate*, whilst the other is the *conducting plate*. To complete the circuit, the plates are brought into contact, or are connected by a wire of varying length, the *conjunctive wire* (Fig. 10). If the amalgamated zinc and the copper plate are placed in

the exciting fluid—diluted sulphuric acid—and are not connected, no effect is observed, but as soon as the circuit is completed by bringing the metals into contact, or by attaching a conjunctive wire, a very decided disturbance is manifested; bubbles of hydrogen gas arise from the decomposition of the water, sulphate of zinc is produced and dissolves in the diluted acid, and a galvanic current passes. When the circuit is broken at any point, action at once ceases.

During the passage of the current, the conjunctive wire acquires new properties, and is changed from its ordinary condition. Its temperature rises, and, if a magnetic needle is brought into its neighborhood, the needle is deflected (Fig. 11). It is found, further, that the deflection of the needle follows a definite law. If the conjunctive wire be placed in the magnetic meridian, the zinc end toward the north, and the needle is then put above the wire, the marked end (north) will deviate eastward; if put below the wire, it will deviate westward. Obviously, the direction which the needle takes is determined by the course of the current. Not only is the direction of the current indicated by the needle, but the strength of the current may, also, within certain limits be measured by the extent of the deviation. The magnetic needle thus becomes a *galvanometer*. To render its indications more certain and precise, some modification of the needle becomes necessary. By employing two needles of the same strength, suspended one above the other, and having their poles opposed, the directive force of the earth's magnetism is overcome, and the combination hence is exceedingly susceptible to galvanic influence.

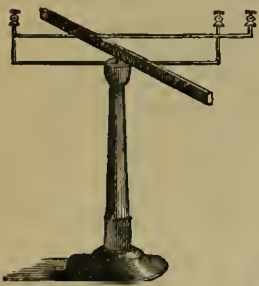
FIG. 11.



Action of the current in the conjunctive wire on the needle.

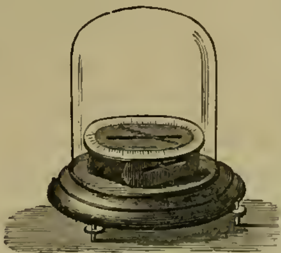
Such a combination is known as *astatic* (Fig. 13). If around the needle there are many turns of fine wire, carefully insulated, and arranged for communication with

FIG. 12.



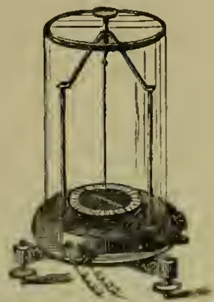
Simple galvanometer.

FIG. 13.



Astatic galvanometer.

FIG. 14.



Another form of the same.

the terminals of the battery, the whole constitutes a galvanometer of much delicacy (Fig. 14).

It has already been demonstrated that, for the production of a galvanic current, two things are essential—chemical action, and on one of two dissimilar metals. The current originates at the point where the chemical action is taking place; hence, in the combination of zinc and copper, the zinc plate is the germinating plate. From this, then, the current sets out (Fig. 10). The direction of the current is in the liquid from the generating plate to the conducting plate—from the zinc to the copper. That the current shall pass from one plate to the other, it is necessary that the intervening molecules of fluid shall be polarized. At the surface, where the chemical action is going on, the galvanism is positive, and consequently the adjacent molecule is, on the side nearest the plate, electrified negatively. As each molecule is in turn thus affected, it is obvious that the conducting plate will be finally reached, and that it will be electrified negatively. When two zinc plates, instead

of a zinc and a copper plate, are inserted in the exciting fluid, this polarization of the molecules cannot take place, for the action, beginning at the surface of each plate, one just counterbalances the other, and no current passes. From the conducting plate the current passes to the conjunctive wire, thence to the germinating plate, thus completing the circuit. Whilst within the battery, the current passes from the zinc to the copper element; outside, it passes from the copper to the zinc, so that, although the surface of the zinc is positive, the copper element outside becomes the positive pole, and the zinc the negative pole.

Electro-motive force is a term used to denote the sum of all the differences of potential effective on a galvanic circuit. In a simple cell the electro-motive force is the difference of potential between the two elements composing it; in the compound circuit it is the result of the combined differences of potential. Current strength is the quantity of electricity transmitted along a conductor per second, the unit of time.

Current of quantity is one having a large volume of electricity; current of tension is one having power to overcome resistance. The resistance to the passage of a current is proportional to the length and sectional area of the conductors. The current from a single large element, immersed in bichromate solution, will redden, even volatilize, platinum wire; whilst the current from twenty medical battery elements, united in series, will barely warm the wire. In the latter case the electro-motive force is diminished by the resistances encountered in each element and in the conductors between them. It follows, therefore, that *the intensity is directly proportional to the electro-motive force, and inversely proportional*

to the resistance encountered within the cell or element, and on the circuit.

$$I = \frac{E}{R + r}.$$

I represents intensity, which is equal to E, the electro-motive force, divided by R internal, and r external resistance. Internal resistance is due to the liquid and to the conducting element, and external resistance to the conducting wires. Applying the law above given, the internal resistance is the greater the further apart the elements are, and the greater the length of the wire connecting them in series.

The unit of electro-motive force is the *Volt*, diminutive of Volta. To give this concrete expression, it may be stated that the volt very nearly represents the electro-motive force (power) of one element of Daniell, which becomes, therefore, the standard of comparison, to which the strength of all other battery elements is referred. The Leclanché element has an electro-motive force of 1.5 volts, and the Bunsen of 1.8 volts.

The unit of resistance is designated the *Ohm*, the name of the discoverer of the celebrated law. The standard of the unit of resistance is a piece of telegraph wire one hundred metres in length and of a certain defined sectional area. A current of electricity passing through such a piece of wire would encounter a resistance which is taken as the unit, or the ohm. As in electric lighting and heating, etc., the performance of a given battery is in part determined by the number of ohms resistance, a standard by which it can be judged is, of course, highly necessary.

The unit of intensity is the *Weber*,[1] the name of a dis-

[1] As no distinguished Frenchman has been represented in this nomenclature, it was proposed at a recent meeting of the International Scientific Congress to substitute the name of *Ampère* for *Weber*, and hence now the unit of intensity is the Ampère.

tinguished electro-physicist. To give this concrete expression, it may be stated that a weber represents the quantity of electricity generated by the unit of electromotive force—the volt, circulating in a conductor having the unit of resistance, the ohm, during the unit of time. It has been ascertained practically that this is the quantity of electricity furnished by an element of Daniell, traversing one hundred metres of certain telegraph wire in the time of a second.

The unity of capacity is the *Faràd*, a contraction of Faraday. One farad is equivalent to one million of *microfarads*. The farad is the capacity of a condenser which holds one weber at a potential of one volt. A condenser of one microfarad capacity contains *about* three hundred circular sheets of tinfoil separated by mica plates, and would be held by a box three and one-quarter inches deep and six and a half inches in diameter.[1]

The forms of elements adapted to medical purposes, and their arrangement in combinations, will be considered most conveniently after an examination of the various kinds now in use in the next chapter.

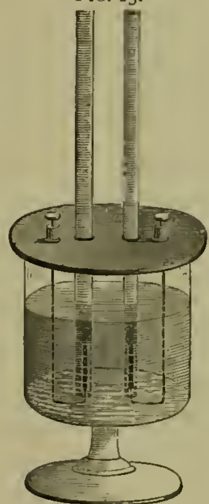
Measurement of Current Strength.—The ordinary galvanometer affords no exact measure of the strength of the current, only its direction. It is very desirable to be able to express in *volts* the strength of a given current, and in *ohms* the amount of resistance. The ordinary galvanometer, or rather galvanoscope, may be converted into an instrument giving the current strength in absolute units, by having the scale graduated in millewebers, and the movements of the needle compared with that of an absolute galvanometer. A gradual approach to a galvanometer measuring in absolute units, and suitable for medical purposes, is making, and then we will

[1] Gordon, Treatise on Electricity and Magnetism. New York, 1880, vol. i. p. 243.

be able to express in exact terms the quantity of electricity administered. The number of cells used does not afford positive information of the current strength, for the electro-motive force and the resistances on the circuit vary greatly from time to time. With a proper galvanometer, the number in millewebers of the current strength is at once known.

Another instrument for determining the current strength is the *voltameter* (Fig. 15). This consists of an apparatus for effecting the decomposition of water by the current, and for collecting its products — oxygen and hydrogen. It is known that the amount of chemical work done by the galvanic current is in proportion to its strength. The quantity of oxygen and hydrogen, therefore, collected in a given time, indicates the strength of the current. It is found that the unit current of one weber, which is one volt working through one ohm of resistance, separates about .115 cubic centimetres of hydrogen in a second, or 6.9 c. c. in a minute. If the tubes receiving the gases are properly graduated, the strength of the current is known from the quantity of the gas obtained. Although not a convenient method of determining current strength for ordinary purposes, it is employed by Ciniselli for ascertaining the strength of current necesssry for coagulating the blood in an aneurismal sac.

FIG. 15.



Voltameter.

Current strength may be roughly tested by touching the tongue, lips, cheeks, or hand of the operator.

Measurement of Resistances. — *Rheostat* is the term

used to designate the instrument by which resistances are interposed in the circuit, and may be liquid, or composed of coils of wire. The liquid used is water, or preferably a saturated solution of sulphate of copper. This is contained in a glass tube, closed with brass caps, and having a movable rod, which is so arranged that any desired stratum of liquid can be interposed between the terminals of brass. According to the thickness of the stratum is the resistance, which having been compared with the scale of standard resistance coils, a special scale can be constructed for the rheostat. A liquid rheostat furnishes approximative results, only. The most accurate instrument for measuring resistances is the wire rheostat, or *resistance coils.* These are coils of German silver wire, of certain definite length and sectional area. The law of resistance of a wire to the passage of a galvanic current is—directly as its length, and inversely as its sectional area. The unit of resistance—the ohm—means the resistance offered to one volt by a wire 200 metres in length. It follows that coils of wire, having a resistance of 5, 10, 50, 500 ohms, may be so arranged as to be interpolated in the circuit. Beside the advantage of having a means of determining the resistance of the body and in the battery itself, the applications of any current strength are greatly improved in smoothness and exactness by the use of resistances.

Processes of Galvanic Discharge.

Although apparently a continuous flow, the galvanic current moves by successive discharges, too rapid to be recognized. The processes of galvanic discharge, by *conduction*, by *disruption*, and by *convection*, employed in

the various practical arts, are also utilized in medical practice.

Discharge by Conduction.—When the two poles of a galvanic battery are brought into different potentials, and are united by a conducting bridge, an equalization of the potential takes place through the bridge, by the flow of electricity from the higher to the lower potential. As has been shown, the conducting bridge or wire—the conjunctive wire—acquires some new properties by the passage of the current; amongst others, its temperature rises. The conductivity of the different metals for electricity varies nearly as for heat. The electric conductivity of metals has been carefully determined, and is found to be as follows: If silver, which is the best conductor, is taken as the standard, or at 100, copper will be about 77, gold about 60, zinc 30, iron 14, and platinum about 10. The conductivity is much affected by impurities, and the above numbers are based on the examination of pure metals. Copper is especially affected in this way, its conducting power being reduced from 50 to 90 *per cent.* by certain impurities. Increase in the temperature of a conducting wire lessens its conductivity, also.

When a current of electricity, which will readily traverse a pure copper wire of a certain sectional area, is made to pass through a finer platinum wire, greatly increased resistance is thus encountered by the current, and the temperature of the platinum rises to a red, to a white heat, or possibly to a temperature at which the metal volatilizes. When a large volume of electricity is made to traverse a small wire, the resistance encountered is so great that the temperature of the wire rises very high. In the arrangement of a battery for heating effects, it is necessary to diminish the resistance at all

points, so that, as far as possible, the current produced can be utilized in heating the wire. These principles are applied in the construction of batteries for caustic effects, and for lighting by incandescence. A platinum wire heated by the current may be used in the form of loop for the removal of pedunculated growths; or a platinum wire or a thin piece of carbon may be rendered incandescent for the purpose of illuminating cavities, etc. These applications of galvanic discharge by conduction will be fully considered hereafter.

Discharge by Disruption.—In the process of galvanic discharge by disruption, a current of high intensity leaps over the distance between the conductors. The brilliant light thus produced is not the electrical current itself, as might be supposed—for electricity is invisible—but is produced by the incandescence of particles thrown off from the terminal. The terminal points usually consist of carbon, and an excavation occurs in the positive carbon, and a deposit is continually made on the extremity of the negative carbon. As the consumption of the points goes on a greater separation of them takes place, and finally the current is unable to leap over the interval. Mechanical contrivances, hence, become necessary to maintain the carbon points at a constant interval. In the various methods of electric lighting by disruptive discharge, the main difficulties in this direction are overcome by special mechanical means.

Discharge by Convection—Electrolysis.—As interesting as may be the other modes of galvanic discharge, the method by convection is the most important. There are certain terms employed in this connection which require explanation. The process of electrical separation of the elements of a compound is called *electrolysis* (from "electricity" and λύσις, releasing). A substance which can be

so decomposed is designated an *electrolyte*. The poles of the battery are called *electrodes* (ὁδὸς, a way), meaning the way the current enters or leaves the electrolyte, or compound, or body, on which it acts.

There are certain laws of electrolysis. An element cannot be further decomposed. Decomposition or electrolysis occurs only when the particles of the body are in a movable state, that is, in solution. During the process of electrolytic decomposition the disengaged substances pass to the poles. Those are termed *anions* which go to the *anode* or positive pole, and those *cations* which go to the cathode or negative pole. As unlike electricities attract, it follows that the anions are electro-negative, and the cations electro-positive substances. Oxygen, chlorine, and the acids appear at the positive electrode; and hydrogen, the alkalies, and the metals appear at the negative, the former being electro-negative and the latter electro-positive substances. The manner in which electrolysis affects the constituents of the body will be discussed hereafter, when the subject of the surgical applications of electrolysis will come up for consideration.

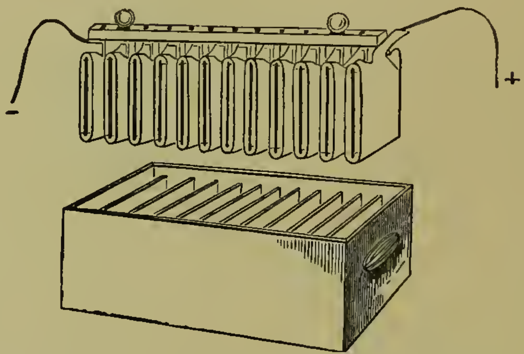
CHAPTER IV.

FORMS OF GALVANIC COMBINATIONS.

The simplest form of a galvanic battery is that to which reference has been so frequently made—a cup containing a zinc generating plate, a copper conducting plate, and an acidulated fluid electrolyte (Fig. 16). Whilst the zinc plate is acted on and dissolved, the electrolyte itself is decomposed into its elements, hydro-

gen appearing at the negative pole. In the more complete batteries, two fluids are employed, the object

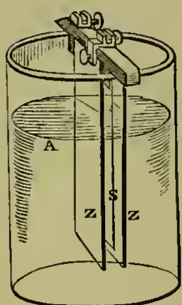
Fig. 16.



Single fluid, zinc and copper elements—trough battery.

being to prevent polarization of hydrogen and of other products of the electrolytic decomposition. Single fluid batteries are more readily portable, and are, therefore, much used notwithstanding their obvious deficiencies.

Fig. 17.



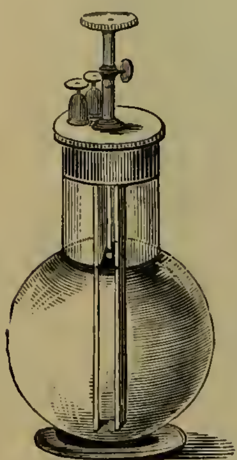
Smee combination. A. Exciting fluid. S. Silver plate, platinized. Z. Zincs.

One of the best known single fluid combinations is that of Smee (Fig. 17). The elements consist of zinc and platinum, which are so widely separated, in respect to their position in the series of electro-positive and electro-negative bodies, that they are well fitted for combination. It has been found that a silver plate, coated with platinum black, is quite as effective in the combination as platinum itself, and is much less expensive. In this battery the exciting fluid is diluted sulphuric acid, and the chemical action consists in the decomposition of water, hydrogen appearing at the platinum, which is the electro-negative element within the

battery, and in the formation of the sulphate of zinc, which is dissolved in the diluted acid. In this combination, the action is prompt, and the force of the current soon rises to the maximum; but, unfortunately, it is not constant, for whilst the maximum is quickly attained, the strength soon drops, and presently falls to zero. This extreme fluctuation in the strength of the current is due to the rapid chemical action, to the formation of sulphate of zinc, which stops the action on the zinc, and to the accumulation of hydrogen on the platinized silver. The great fluctuations in the strength of the current from the Smee battery, and the care necessary to keep it in order are serious objections to its use for medical purposes.

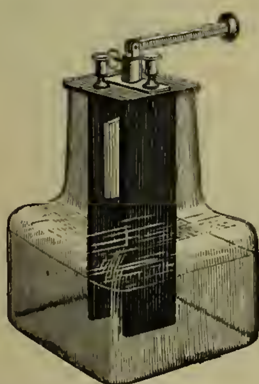
Probably the best form of single fluid battery is the cell of Grenet (Fig. 18). Zinc and carbon are the

FIG. 18.



Grenet cell.

FIG. 19.

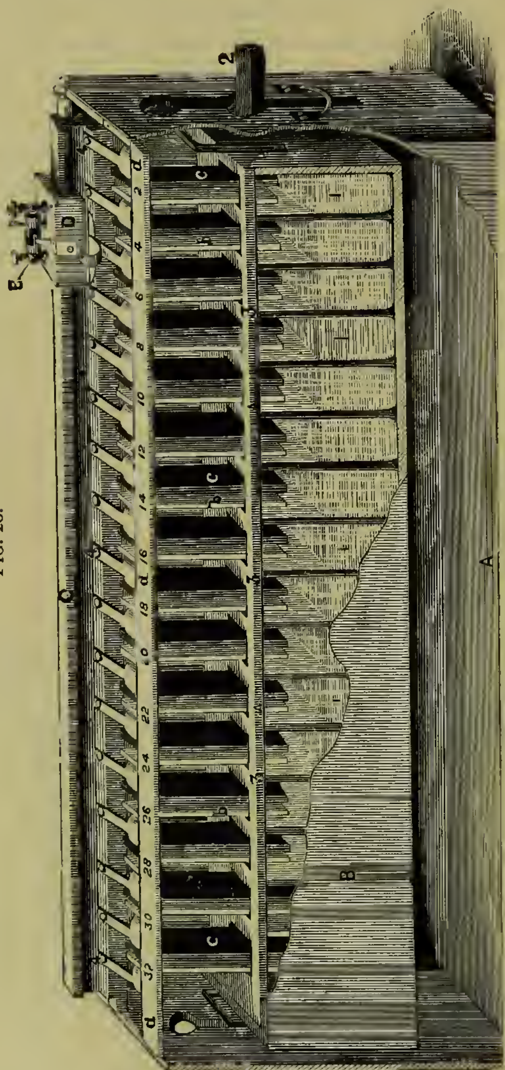


Another form of Grenet's cell.

elements, and the exciting fluid is an acid solution of bichromate of potassium. The chemical action is similar to that of the Smee, but in this the hydrogen is appro-

priated so that it does not accumulate on the carbon plate. The Grenet cell, further, has an arrangement for

Fig. 20.



Stöhrer's zinc-carbon combination, as made by the Galvano-faradic Company of New York. The side of the main case is cut away to show the arrangement by which the cells, I, are lifted up by the handles, 2, to the elements.

lifting the zinc out of the fluid when not in use (Fig. 19). Although more constant than the Smee, there are the

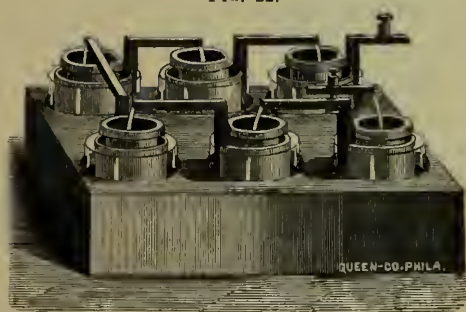
same objections to it as to a constant battery: the current rapidly attains the maximum, and then falls to zero. In the Stöhrer batteries, the same form of elements and the same exciting fluid are employed. The Stöhrer constant battery has an arrangement by which the elements can be raised out of, or lowered into, the fluid. For the portable battery, Stöhrer's combination may be regarded as the best, except the Leclanché, but it does not compare with some other cells for the construction of a permanent battery (Fig. 20).

A battery to be constant must contain two fluids. In those of two fluids, the polarization of the hydrogen, and of other products of electrolytic decomposition, is sought to be prevented by certain chemical reactions, and by mechanical means. One of the most powerful of these is Grove's "nitric acid battery." The elements are of zinc and platinum. The zinc element is acted on by diluted sulphuric acid, and the conducting element—the platinum—is suspended in nitric acid contained in a porous cup (Fig. 21). By this arrangement, polarization

FIG. 21.

Grove's element.

FIG. 22.



Grove's battery.

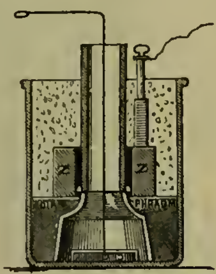
of the hydrogen is prevented by its entering into combination with a portion of the oxygen of the nitric acid, reducing it to hypo-nitrous, the fumes of which are given

off when the battery is in action. The porous cup acts mechanically as a diaphragm to prevent the deposit of zinc on the platinum, which, in this arrangement, is kept clean and bright, and therefore in the best condition to conduct the current (Fig. 21). In the combination known as the Bunsen, the arrangement of the elements is the same as in the Grove, except that the negative plate is carbon instead of platinum. The price of such a combination is much less than the Grove, but the carbon does not long retain its properties, and must be frequently well washed and baked over.[1] When the carbons are fresh, the action of this battery is very powerful, somewhat more powerful than the Grove, but it is not as constant as the latter. Owing to the fumes given off by them, and the expense and trouble of their manipulation, these two forms of constant battery of two fluids are not adapted to medical uses. Probably the best of the two fluid batteries, as it was first invented, is Daniell's. The elements are of zinc and copper, separated by a porcelain or baked-clay diaphragm. The zinc is immersed in diluted sulphuric acid, and the copper in a saturated solution of sulphate of copper. Sulphate of zinc is formed, the sulphate of copper is decomposed, the copper is deposited on the copper, and the sulphuric acid diffuses through and reinforces the acid attacking the zinc. The hydrogen is here utilized in the decomposition of the sulphate of copper solution. To render the action constant, crystals of sulphate of copper are kept in a basket suspended in the copper solution, thus maintaining the solution at the point of saturation.

[1] The carbon for battery purposes is gas carbon. It is mixed with treacle, put into suitable moulds, and baked in an oven. When its properties are impaired, they may be almost entirely restored by washing the carbon thoroughly and subjecting it again to the heat of the oven.

The Daniell combination is of especial medical interest, because, as modified by Siemens and Halske, under the direction of the celebrated Remak, it has been, and continues to be, the favorite combination for medical purposes on the continent of Europe and with many in this country. In the modified Daniell cup, the copper element is in the form of a rosette, and is sursounded by a saturated solution of the sulphate of copper, which is maintained at the point of saturation by a number of crystals. Over the copper element is placed a cup-shaped, inverted, porous diaphragm, and around this is packed a quantity of paper pulp, or soft *papier-mache*, which supports the zinc element. Around the zinc and covering it is water only. The sulphate of copper is decomposed, copper is deposited on the copper rosette, and the sulphuric acid diffuses through to attack the zinc (Fig. 23). This form of battery requires but little attention. Water is needed every few days to supply the loss by evaporation, and some crystals of copper sulphate must be dropped into the copper solution occasionally. The action of this battery is remarkably constant, and it will continue so for months, requiring no further attention than adding a little water. The action on the zinc is slight, and the resistance within the battery about equal to that of the body—hence the smoothness of the current. After the first expense of construction, there is but little required to keep it in good working order. For the purpose of a permanent battery it is, in the author's experience, the best. After many trials and

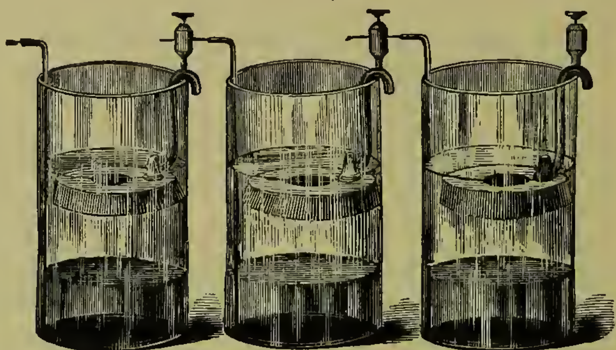
FIG. 23.



Siemens and Halske's modification of the Daniell element, as made for Remak.

failures, I have finally adopted this form, and have a battery of 100 elements permanently arranged in my office. Sixty of these have now been running eight years, and the zincs, although much worn, are still nearly all serviceable. The cup should have a capacity not less than two quarts, and the zincs should be about three inches in height, an inch in thickness, and twelve inches in circumference, less a space of two inches, so that they can be removed without disturbing the connections of the copper element. Another modification of the Daniell cup, now much employed for telegraphy, is "Hill's gravity battery" (Fig. 24). In this arrange-

FIG. 24.



Hill's gravity element.

ment the copper element consists of a large copper plate which rests on the bottom of the cup, and the zinc element, also a broad disk having a large orifice in the centre, is suspended by a hanger from the side of the cup, reaching down about midway. The copper element is surrounded by a saturated solution of sulphate of copper, and the zinc element by a solution of sulphate of zinc. They are kept apart by the difference in specific gravity. The copper solution is kept saturated by dropping crystals of the sulphate through the

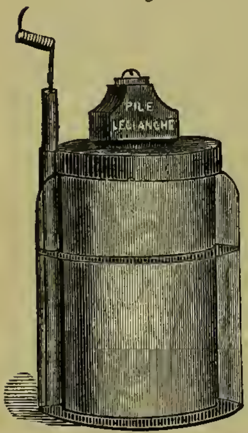
fluid and through the opening in the zinc element. The cells must not be agitated, lest diffusion take place, and the surface of the zinc solution should be covered with a layer of paraffin to prevent evaporation. This form of cup is found to answer very well for medical purposes, and is especially praised by Hammond. Another modification of the Daniell, made by Trouvé, consists of disks of copper and zinc, the former covered by paper pulp, moistened with a saturated solution of sulphate of copper, and the latter covered with paper, moistened with sulphate of zinc solution. Trouvé has also improved the gravitation battery. Forty elements of either form suffice for most purposes.

The chloride of silver battery is also a very efficient combination. As made by Gaiffe, of Paris, it is very much praised by De Watteville. The cells are less than three inches in length and one inch in diameter, and are composed of zinc and silver rods in a vulcanite cup. The elements are separated by a fold of bibulous paper, moistened with chloride of zinc solution (three per cent.), and at the bottom of the cup is placed some chloride of silver. The electro-motive force of this cell is about 1.5 volt. Another convenient combination is the sulphate of mercury element, composed of zinc and carbon rods, placed in a test-tube and separated by saw-dust, moistened with acidulated water, and having a thick layer of sulphate of mercury at the bottom. These elements are put in a box, the top of which is a pole-board containing selectors, galvanoscope, rheophores, etc.

The element of Leclanché, which is patented, is largely used in this country by the district and house telegraph, burglar-alarm, etc. It is much praised by some French electricians, and by Poore, who regards it superior to all other forms of galvanic combination. As it is patented,

it can be repaired only by the agents of the owners. The elements are composed of zinc and gas carbon, the latter placed in a porous cell and surrounded with native peroxide of manganese, mixed with coarsely-powdered carbon. The porous cell with its contents is placed in a glass vessel of quadrangular shape containing a saturated solution of ammonium chloride (sal ammoniac) and a rod of zinc. Ammonia is set free and absorbed by the water, chloride of zinc is formed, and hydrogen is set free, but its polarization is prevented by combination with the oxygen of the peroxide of manganese.

FIG. 25.



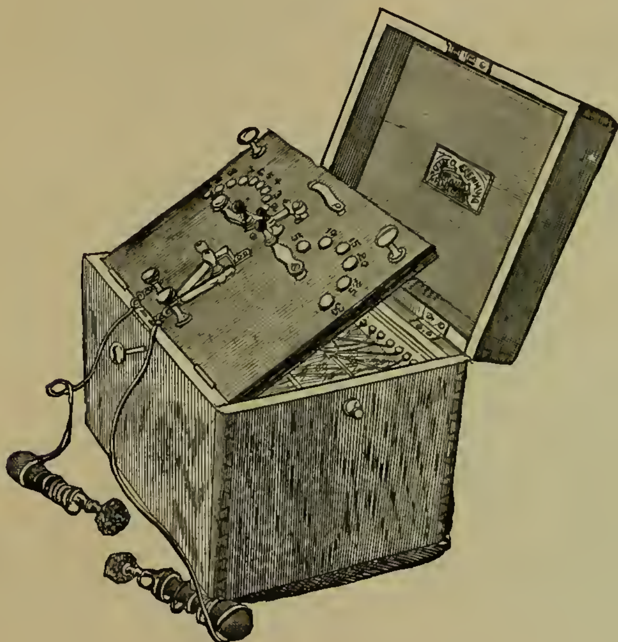
As the cup is carefully sealed, escape of its contents cannot take place, and hence this combination is very useful for portable batteries, since the cups can be obtained from two ounces upwards (Fig. 25). A Leclanché battery, portable, of thirty small elements, and having a pole-board containing selectors, reverser, and galvanoscope, has been constructed for me by O. Flemming, of Philadelphia. It is efficient, small in size (eleven by eight inches), and readily transported (Fig. 26).

How must Cells be Arranged?

In the construction of batteries for medical purposes, the arrangement of the cells is determined by the purpose for which the battery is to be used. For the same metal and the same acid solution, the electro-motive force is the same, whatever may be the surface of the metal immersed, and the volume of the liquid. Whilst

the current from a single large cell in bichromate of potash solution will redden, even volatilize, a platinum wire, twenty elements of the size usual for medical batteries will barely warm the same wire. In the latter there are twenty times more electro-motive force and

FIG. 26.



twenty times more tension; but the energy is diminished by the resistance in each element, and hence the quantity of electricity available for use is much less than in the single large element.

When the cells are united, zinc to zinc, and copper to copper, the combination is a "simple circuit;" and when the zinc of one cell is united to the copper of the next, and so on throughout the whole number, the combination is said to be a "compound circuit," or "in series."

If we take the Daniell element for illustration, the problem is simplified. The Daniell has an electro-motive force of one volt, and, if joined in series, thirty will have the force of thirty volts; but if joined in simple circuit, will have an electro-motive force of one volt only, but will constitute a large plate thirty times the size of one plate.

If the reader will now recall that intensity is the power to overcome resistance, and that

$$I = \frac{E}{R + r},$$

and that the resistance of the human body is thousands of ohms, he will at once comprehend that a battery for medical applications must be arranged in series. *The best results are attained when the interior resistance of the battery is equal to the resistance on the exterior circuit.* Applying this principle, what will be the arrangement when the battery is to coagulate the blood of an aneurismal sac, the resistance of which is about eight ohms? As the external resistance is so small, the internal must correspond. As the internal resistance of the element of Daniell is twenty or more ohms, this is not suited to this particular purpose. The zinc carbon combination of Stöhrer or Grenet, arranged in simple circuit in pairs, of which four will furnish the necessary electro-motive force, are appropriate. A combination of elements for heating a platinum wire, which has a resistance of one-half an ohm, must have, consequently, a minimum of resistance. Large plates united in simple circuit, and as closely placed as possible, are required; and on this principle caustic batteries are now made.

The guiding principle in the selection of the element for forming a battery for medical purposes, is that the interior resistance of the battery element shall equal the

resistance of the human body. It is this, amongst other reasons, which renders the element of Daniell, as modified by Siemens and Halske for Remak, so useful and desirable for medical practice. The internal resistance is so increased by the papier-mache packing and the porcelain diaphragm, that it equals the resistance offered by any part of the body. Hence it is said to be smooth and unirritating when the same number of elements of Stöhrer give rise to great irritation and burning. In this fact we find the true explanation of the superiority in curative action of the large elements in a permanent battery, as compared with the small elements of a portable battery. Boudet,[1] recognizing the importance of this principle, advises that materials having imperfect conducting power be interposed between the surface of the zinc and the conducting element to increase the internal resistance. Such elements are remarkable for their constancy and uniformity. The Siemens and Halske element will remain in use, furnishing a current of uniform intensity for a year at a time, requiring only some crystals of blue vitriol and sufficient water to cover the zincs occasionally. It may even be short circuited for days without impairing its strength, whereas a Leclanché would run down in a few hours under these circumstances.

Galvanic batteries are portable or permanent. The portable consist of small elements (Smee, Grenet, Stöhrer, etc.) and a single fluid, and are so arranged that the elements can be lowered into or raised out of the exciting fluid when not in use (see Fig. 18). The permanent batteries are composed of large cells with two fluids, and are fixed in some convenient position. Whether movable or not, a battery of many elements requires

[1] Revue de Médicine, Sept. 10 to Oct. 10, 1881.

mechanical contrivances for working it. The portable batteries are fitted with a movable "selector," which is so arranged that various numbers of cups can be interpolated in the circuit. Permanent batteries are arranged in combinations, and are worked by a pole-board on which are placed brass knobs communicating with the various sets or combinations of cups (Fig. 27). These

FIG. 27.

Flemming's key-board.

sets are on one side usually from one to ten, and on the other from ten to fifty, sixty, ninety, or any other number of cups of which the battery may be composed. By means of a selector any possible number of cups from one up to the limit of the battery may be selected for the desired application. The pole-board should also contain a "polarity changer," an arrangement for quickly changing the poles, a "commutator," and an "interrupter" (rheotome), which may run either by clock-work or by an electro-magnet, for interrupting the current slowly or quickly as may be necessary. Besides these, pole-boards are usually supplied with a galvanometer, a rheostat, or Brenner's resistance coils. The galvanometer, which, theoretically, measures the force of the current, does not actually afford constant and reliable indications, and can

be depended on only to indicate the direction of the current. The cheek and tongue of the operator become in actual practice the most delicate and trustworthy galvanometer. Most pole-boards are supplied with a water rheostat by which different degrees of resistance are brought within the circuit, but for any nice determination the resistance coils of Brenner are necessary. As the resistance offered by a wire depends on its length and the area of its section, it is obvious that, by having coils of certain standards of length and thickness, a fixed and definite amount of resistance can be introduced into the circuit. Such are the resistance coils of Brenner (Fig. 28). The Siemens' unit of resistance consists of

FIG. 28.

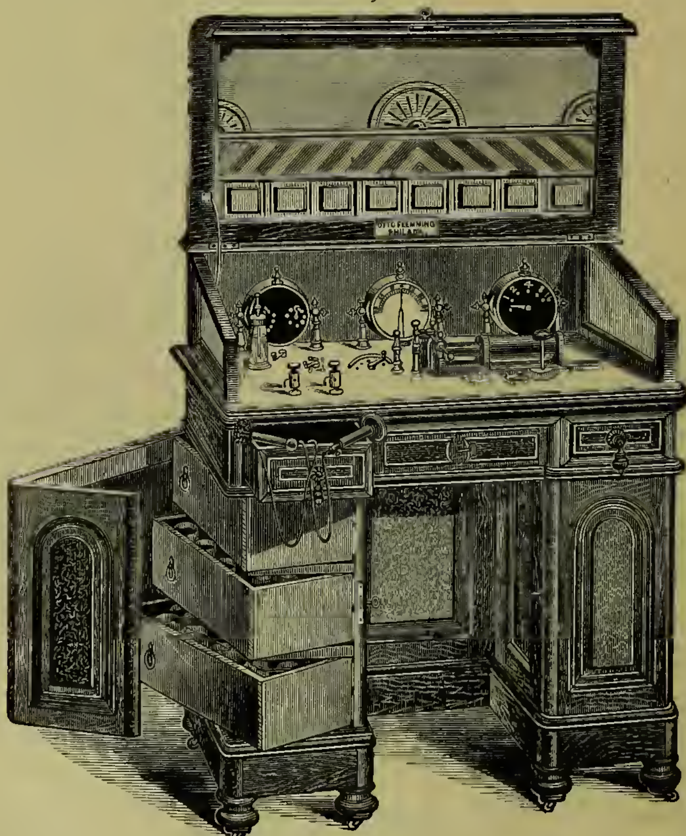
Resistance coils.

mercury having the temperature of 0° C., contained in a glass tube one metre long and one square millimetre in section. As this is an arbitrary standard, it cannot be connected with any absolute system of measurement. That which is now employed chiefly is known as the B. A. unit, because introduced by the British Association. It is also called the Ohm. It is based on the principle that the resistance of a uniform wire of given material is proportional to its length, divided by its weight. In the

resistance coils, the resistance is known in absolute measure, and to them all other wires are referred. The B. A. standard, or unit coil, is a wire composed of an alloy of 66 per cent. of silver and 33 per cent. of platinum, which was finally selected by the committee of the association as superior to all others.

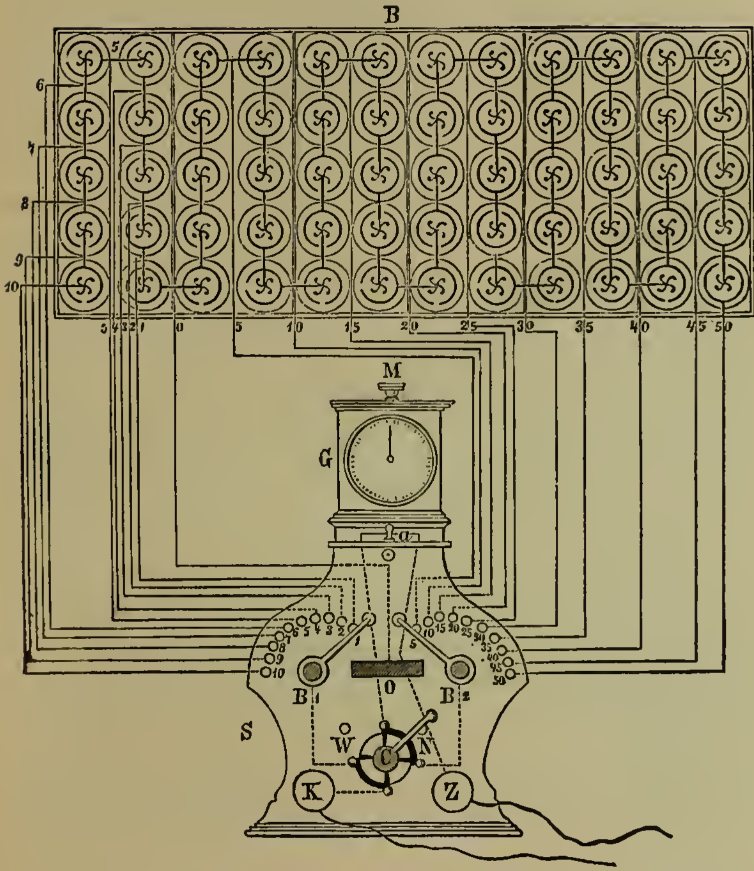
The pole-board may be placed in the office, consulta-

FIG. 29.



The Flemming cabinet battery. This cabinet battery is arranged with movable boxes which contain the cups or elements, and the pole-board having a current selector, a galvanometer, a water rheostat, an induction coil, etc. This is intended for office use only, and is an elegant piece of furniture as well as a convenient battery.

FIG. 30.



Remak's battery. This diagram is intended to illustrate the original arrangement of galvanic battery and key- or pole-board adopted by Remak. The battery is composed of 60 elements of Daniell, as modified by Siemens and Halske, connected with an upright key-board which is supposed to stand as an office table. The cups are arranged in two sets: On the left-hand side 10, commencing at 0, which is attached to the central-plate on the key-board, and on the right 50, arranged in combinations of 5. The key-board contains a galvanometer, G, which can be cut off at *a;* current selectors, B; a polarity changer, W N, which is interposed so as to affect the current passing from the cups to the electrodes, K Z. The battery, B, can be put into the cellar, a closet, or cabinet, and the key-board may stand on a table in the consultation-room. The key-boards now made by the American dealers are much superior to this, which is chiefly interesting on account of the association with Remak.

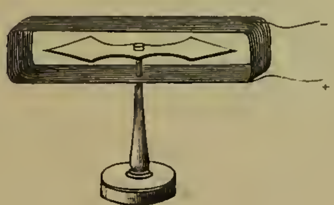
tion-room, or ward of a hospital, and the battery elements at a distance—in the cellar usually. They communicate by means of insulated telegraph wire—wire coated with gutta-percha (Fig. 30). The portable battery, on the other hand, may be carried to any point—to the bedside of the patient, if necessary. On first view it might appear that the portable battery is more convenient and useful than a permanent arrangement. When we come to investigate further, we find that portable batteries require much care, and need to be frequently cleaned and recharged to preserve their activity. They furnish a current of relatively high tension and small volume, which is not capable of effecting the same therapeutical results as a battery containing larger elements. Furthermore, no portable battery of a single fluid furnishes a truly constant current, for, although a galvanic current, the variations in tension are sudden and considerable. When the battery is freshly charged, the current rises immediately to the maximum, but soon declines to a greater or less extent. Of course, this variation of tension only occurs with a single fluid battery. If the portable battery were composed of elements of Leclanché, it would have all the advantages of a permanent battery except in regard to the size of its elements.

CHAPTER V.

ELECTRO-MAGNETISM.

WHEN the galvanic current is passing through the conjunctive wire of the battery, the wire becomes a magnet, and will attract iron-filings, but when the current ceases, the magnetic property does also. When the conjunctive wire thus becomes a temporary magnet, if an astatic needle is brought near to it, the needle assumes a position at right angles to the direction of the current in the wire (Fig. 31). Just as a permanent

FIG. 31.



Needle surrounded by a coil of insulated wire. When the current is made to traverse the coil, the needle is deflected. Represented at rest.

FIG. 32.

A bar of iron wrapped with insulated wire. When the current passes, the weight is firmly attached.

magnet may induce the magnetic property in a piece of iron, so the conjunctive wire—temporarily a magnet—can induce the magnetic property in a bar of iron (Fig. 32). Thus, take a bar of iron in the horseshoe shape, and coil around it an insulated wire, which communicates

with, and is an extension of, the conjunctive wire; it will be found, as soon as the current traverses the wire, that the iron has acquired strong magnetic property, and powerfully attracts another piece of soft iron—the anchor or armature—so strongly that considerable force is necessary to separate them. When the circuit is open, the horseshoe ceases to be a magnet, and the anchor at once falls away. Such a temporary magnet is an *electro-magnet*, because the magnetism exists only when the electricity is passing.

It was the Danish philosopher, Oersted, who, in 1819, discovered the influence of the conjunctive wire on the magnetic needle. The next step in the progress of discovery was the demonstration by Arago, in 1829, that the electric current can induce magnetism in iron and other bodies. It remained for Faraday to complete the discoveries by showing that a galvanic current can induce electrical currents in conducting wires. If the conjunctive wire of the battery, coiled on itself and properly insulated, is laid on an insulated surface, and in its immediate neighborhood is placed another coil of insulated wire, connected with a galvano-multiplier, it is found that when a current is passed through the former, the needle of the multiplier is on the instant deflected, then it oscillates a little, and presently comes to rest. If, now, the circuit is opened, the needle is again deflected, but this time in the opposite direction (Fig. 33). Instantaneous currents are, therefore, induced in one wire by a galvanic current passing in another wire near. The wire connected with the battery transmits an inducing current; the secondary wire transmits an induced current; but the latter is instantaneous, and exists only at the opening and closing of the circuit. The needle of the galvano-multiplier, or galvanometer, not only

shows that instantaneous currents are induced, but also indicates their contrary directions. The induced current, starting on the breaking of the circuit, is more powerful than that starting on making of the circuit. On closing the circuit, the direction of the induced current is opposite to that of the inducing; on opening or breaking the circuit, the induced current is in the same direction as the inducing current. It is, therefore, a to-and-fro current, instantaneous, and not, like the galvanic current inducing it, a continuous current passing in one direction.

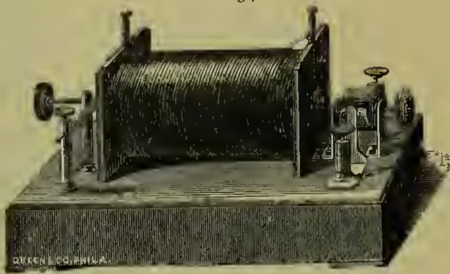
Fig. 33.

The larger coil—the primary coil is connected by the binding screws at the bottom with the battery. When the secondary coil, which is connected with the galvanometer, is lowered into the primary, a current at once starts in the former, as shown by the movements of the needle. A current starts in the other direction when the secondary coil is withdrawn. The galvano-multiplier connected with the secondary coil is not shown.

It was soon ascertained that much more powerful instantaneous currents are produced if two wires of very great length, carefully insulated, are rolled into coils, and placed near to each other. The wire of the inducing coil is, however, always shorter and thicker than that of the induced. In this way the surface for inductive action is enormously increased (Fig. 34). In the Ruhmkorff coil, which, if of large size, will furnish sparks an inch or more long, there are hundreds of yards of very fine wire in the induced coil. It was further ascertained that the intensity of the induction current derived from the coil is greatly increased by introducing some pieces of soft

iron in the cavity of the coil· or bobbin. When the current passes, the soft iron becomes magnetic, just as the horseshoe bar does when the current traverses the wire wrapped around it. The magnetized soft iron, in turn, acts on the wires about it, and hence exalts the

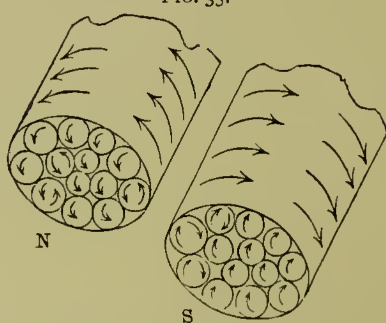
FIG. 34.



Ruhmkorff's coil.

action in them, or increases the strength of the current (Fig. 35). The soft iron induces instantaneous currents in the coil at the moment of acquiring and of losing its

FIG. 35.



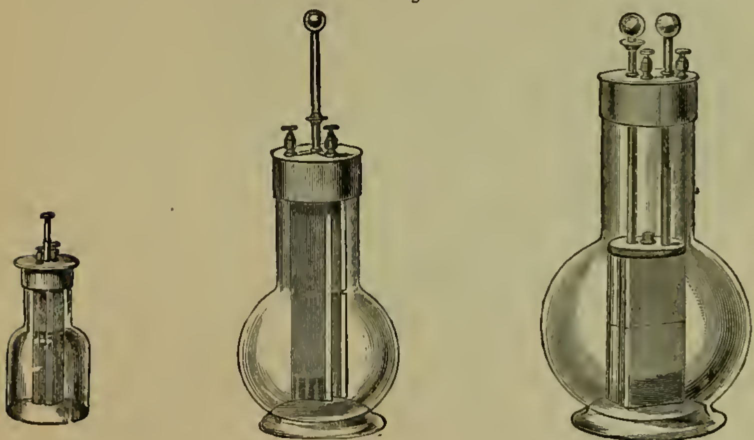
Induction in a core of soft iron contained in a bobbin or coil of insulated wire.

own magnetism. This effect is still heightened if the soft iron put into the core of the bobbin is composed, not of a single piece, but of a bundle of wires or needles, each one of which is insulated from the rest by a layer of varnish.

The important contributions of Faraday, to our knowledge of these facts, have coupled his name to this form of electro-magnetism, which is hence known as Faradism or Faradic electricity. The successive steps in the progress of discovery have been stated, to render clear the construction of the apparatus by which the force—electro-magnetism—is utilized in medical practice.

The electro-magnetic or faradic battery consists of the galvanic couplet, or of two; of the inducing coil,

FIG. 36.



No. 1. No. 3. No. 4.

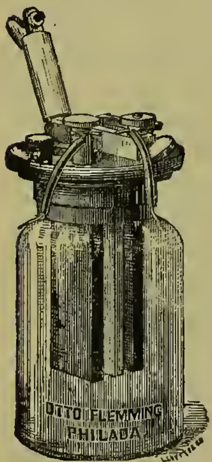
The Grenet cell.

which is an extension of the conjunctive wire of the cup; of a rheotome or current interrupter; of a secondary coil, in the same bobbin with the primary coil; a bundle of soft iron wire in the core of the bobbin; polarity changer; electrodes, etc.

The couplet (Figs. 36, 37) now most frequently used, and the best for this purpose, probably, is the Grenet, which is composed of zinc and carbon elements, and has an arrangement for lifting the zinc out of the fluid. The Smee combination is also a good deal used, but platinized

silver is substituted for platinum. It is rare, indeed, that more than one cup is required in the ordinary applications of a faradic battery; hence, for the most part, a single-cell battery suffices for the physician. The inducing wire, as said above, is an extension of the conjunctive wire of the battery, and is comparatively short and thick. About this is coiled numerous turns of fine wire, carefully insulated, and the two coils constitute the bobbin. The reader must now clearly understand that the electricity is induced in the secondary coil only at the moment when the current begins and ends—at the closing and opening of the circuit. Hence, there must be an arrangement for interrupting the current in the primary or inducing wire. This is now accomplished by an ingenious automatic interrupter, known as Neef's hammer. This consists of a steel spring terminating in a hammer, of such length that the hammer vibrates in front of the soft iron in the core of the bobbin. On the steel spring, about its middle, is a small plate of platinum, and resting against this is a screw tipped with platinum at its point, and so arranged that the screw regulates the excursions of the hammer, or the rate of its vibrations. This constitutes an automatic interrupter. It is contained in the circuit of the primary coil. Its mode of action is as follows: When the circuit is closed, the soft iron core of the bobbin is at once rendered magnetic, and attracts the hammer to it, and in so doing breaks the circuit at the platina-tipped screw; at once the iron is demagnetized, and the spring

FIG. 37.



The Flemming battery cell.

draws the hammer back by its own resiliency; then again the circuit is closed, the soft iron is again magnetized, the hammer attracted, and thus there ensue regular in-

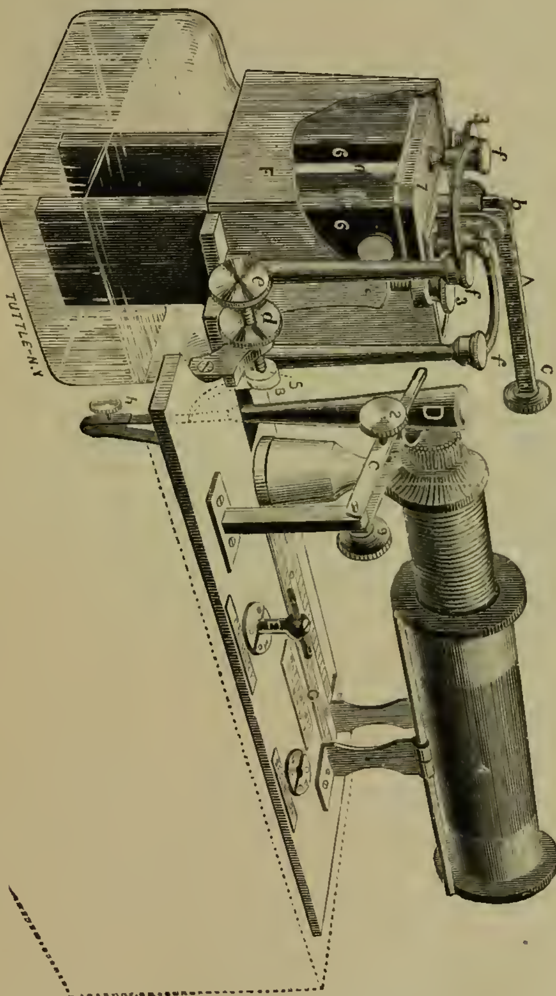


FIG. 38.

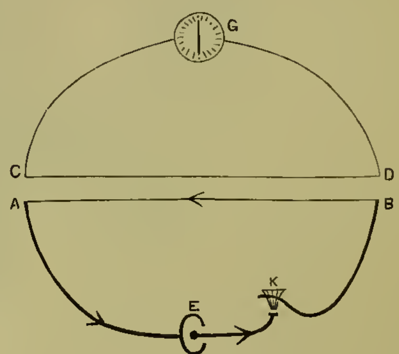
The Galvano-Faradic Company's faradic instrument. The cell is a Grenet. The interrupter is peculiar. It consists of a fork, C, a hammer, D, which plays in the fork. *c*, *d* is a double thumb-screw to regulate by its point, 5, on the disk of the hammer-spring the number of the vibrations. The coil, the core of soft iron, and movable cylinder are also shown in this figure.

terruptions. The steel spring is also called "the trembler," from the rapidity of its movements. Although the platina-tipped screw is intended to regulate the

number of interruptions, it does so to a very limited extent; the vibrations of the spring are very rapid, and can be but slightly diminished. The hammer of the faradic apparatus invented by the Galvano-Faradic Company, of New York, plays in a fork which enables the operator to regulate the interruptions to any extent (Fig. 38). In the faradic instrument of Flemming, of Philadelphia, the same end is attained by a mechanical arrangement for regulating the rapidity of the interruptions. In an instrument provided with this arrangement, distinct contractions and relaxations of the muscles operated on can be obtained, whilst by the other hammer the interruptions are so rapid as to keep the muscles in a state of tonic contraction.

The mechanism of the construction of a faradic battery will be more readily comprehended by reference to these instructive diagrams from De Watteville. In Fig. 39 we have the parts reduced to their simplest expres-

Fig. 39.

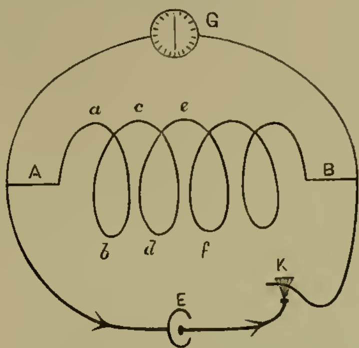


sion. The primary coil, an extension of the conjunctive wire, is represented by the line drawn from A to B. The galvanic element is E, and at K is the interrupter. Whenever the current is made or broken at K, an in-

duced current starts in the coil represented by the line from C to D, and the needle of the galvanometer is deflected in one direction at the making, and in the opposite direction at the breaking, of the circuit.

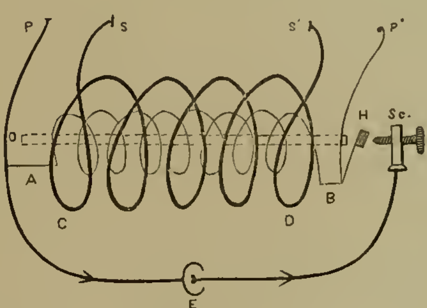
In the next diagram, another point, viz., the induction between the turns of the coil is expressed. In Fig. 40,

FIG. 40.



we find that a current passing through A, B, induces a current in C, D. Precisely the same effect is exerted between the turns of the coil *a*, *b*, *c*, *d*, *e*, *f*, and the

FIG. 41.



current thus induced on the opening and closing of the circuit at K, affects the needle of the galvanometer, as in the other diagram. In Fig. 41, the whole construction

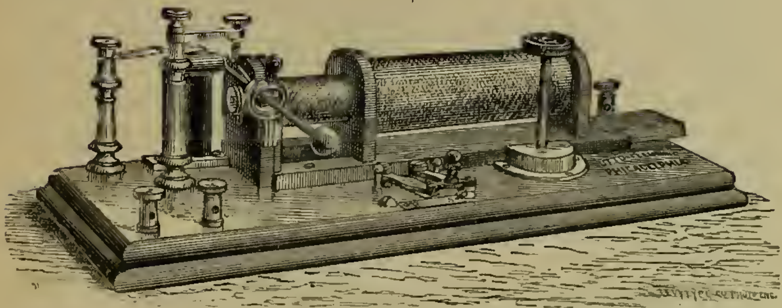
of the faradic battery is shown diagrammatically. Instead of a straight line, the primary coil is represented in the finer line in a coil from A to B, and the secondary coil is shown in the broader line of C to D. The central core is the dotted line extending through the coils. The interrupter consists of the screw Sc, and the flexible hammer H, vibrating between the core and the screw. P, P′ are the primary poles, and S, S′ the secondary. When the current from E passes through the screw Sc, the hammer H is attracted to the screw, and the circuit through the coil from B to A is complete. At this moment the soft iron in the interior is magnetized, and then the hammer H is attracted to the iron and the circuit is broken. At every interruption, currents of induction start in the secondary coil C, D, and induction takes place between the turns of the coil, thus reinforcing the primary current, the poles of which are at P, P′. Induction also occurs between the turns of C, D, thus reinforcing the secondary current, the poles of which are at S, S′.

The current thus produced, which Faraday called the "extra current," is collected in some of the modern faradic instruments and made to do duty as "the primary current." The current induced in the secondary coil is also, as has just been stated, improved by the currents produced by induction between the coils. Hence it follows that, if these accessory currents be cut off from the main ones, the strength of the latter would be correspondingly reduced. This is accomplished by a movable cylinder, which is pushed in or out when it is desired to increase or diminish the strength of the applications.

In many of the foreign instruments—Du Bois Reymond's, for example—the secondary coil is made to slide over the primary, so that very nice gradations in

the strength of the secondary current can be effected (Fig. 42).

FIG. 42.



Improved Du Bois Reymond coil. This coil is provided with slow and rapid interrupters, with switch for making connections with the primary and secondary current, and with governing screw for regulating the tension of the current.

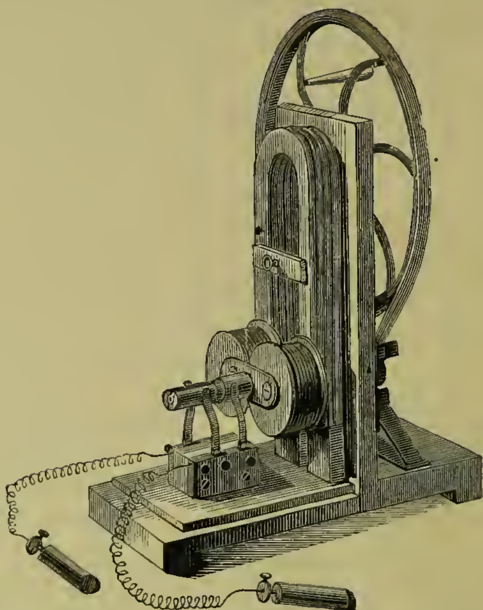
CHAPTER VI.

MAGNETO-ELECTRICITY.

By the passage of galvanic electricity through a coil of insulated wire, the magnetic influence is induced in a bar of soft iron, about which the wire is wrapped. Faraday inferred that the same result would follow a reversal of the experiment—that a permanent magnet would induce an electric current in a coil of wire subjected to its influence. This is readily demonstrated. Connect a coil of insulated wire with a galvano-multiplier, and quickly approach and withdraw a permanent magnet. Both when the magnet nears and is withdrawn from the neighborhood of the coil, instantaneous currents are induced in the coil, as is shown by the movements of the needle. When the magnet approaches the coil, the current moves in one direction; when it is withdrawn, the

current moves in the opposite direction. To produce a succession of such currents, it is only necessary that the magnet be rapidly approximated to, and as rapidly withdrawn from, the coil of insulated wire on which it exerts the inductive action. In the magneto-electric machine it is found more convenient to approximate to and withdraw the coil from the magnet which is fixed in position (Fig. 43). The coil is made to revolve about

FIG. 43.



Magneto-electric battery. In this battery the magnets are placed vertically, and the coils are made to revolve rapidly by the large wheel.

the poles of a permanent magnet, or one or more magnets clamped together to obtain greater power. By means of a crank and wheels, the coils revolve with great rapidity. As a core of soft iron, acted on by the current in the coil of the electro-magnetic machine, by its magnetization and demagnetization, reinforces the current,

so in the magneto-electric machine the to-and-fro current induced in the coil is reinforced by the magnetization and demagnetization of the soft iron horseshoe about which the coil is wrapped.

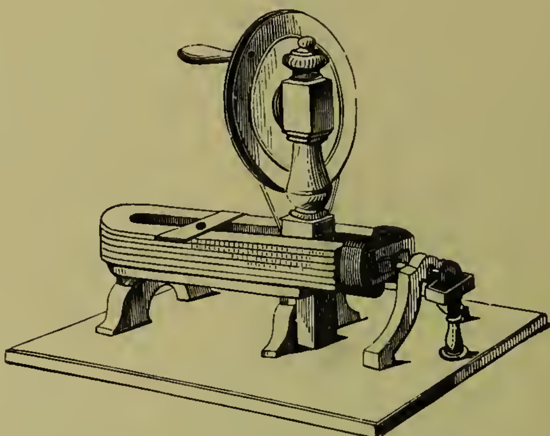
In the magneto-electric machine of Duchenne, the coils are fixed to the magnet instead of to the armature. By this arrangement the current of induction is due to variations in the magnetic state of the magnet. Gaiffé has successfully combined the two systems, and has fixed one pair of coils to the armature, the other to the magnet. A great increase of power is thus gained. The coils may be constructed for high or low tension—in the one case made of fine wire; in the other, of coarser wire.

The alternating, or to-and-fro current of the magneto-electrical machine, may be converted by a suitable commutator into a current of one direction. By a very simple arrangement, as the commutator catches each current, it is so timed on its revolution as to send both in the same direction. The current of one direction has the chemical and heating effects of the galvanic. It is obvious that the arrangement of such a battery for medical uses will be governed by the principles already laid down. Suppose it to be intended for application to the human body, which has very high resistance? Remembering the fundamental rule that the best effects are produced by elements in which their internal resistance is about equal to the resistance on the exterior circuit, the magneto-electric machine must have coils which offer a degree of resistance to the circuit about equal to the resistance of the body. Now, as the resistance of a wire is directly as its length, and inversely as its sectional area, it follows that a magneto-electric battery for applications to the body should have a coil of long and fine wire. If, on the other hand, it were intended for elec-

trolysis or for heating a platinum wire, the resistance being low, the coil should be made of a thicker and shorter wire.

Magneto-electric machines are now constructed on a large scale for electric lighting, electro-plating, and other purposes in the arts. Powerful magnets are used, and steam-power is employed to obtain the necessary rapidity of the revolutions. By means of the ingenious commu-

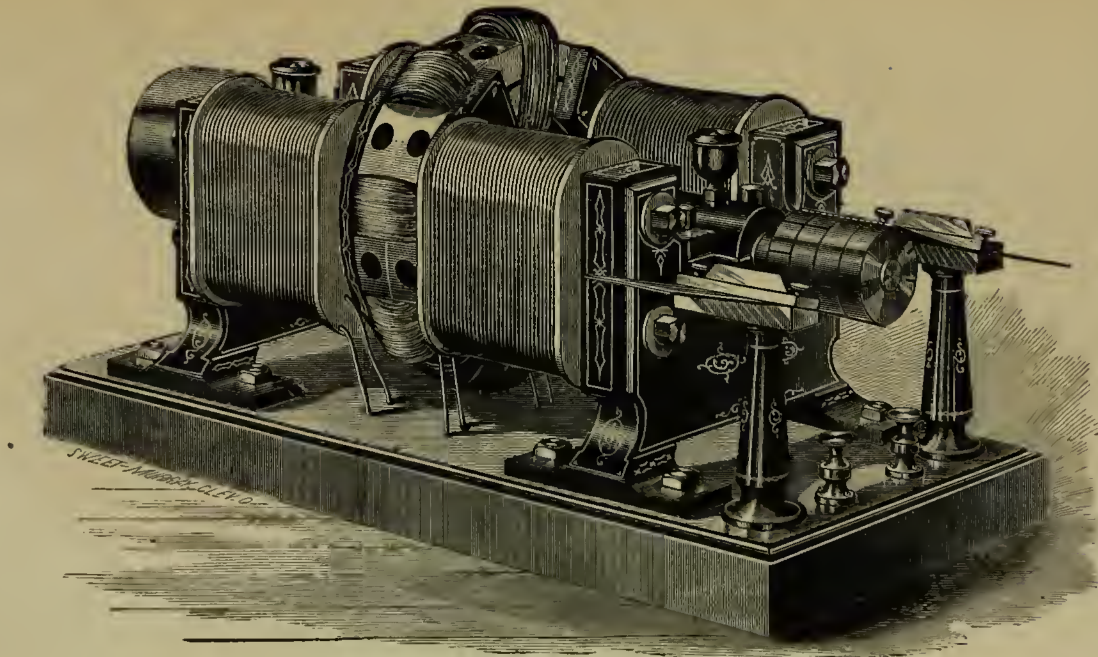
FIG. 44.



Magneto-electric machine. Another form. In this machine the magnet, composed of several bars clamped together, is placed horizontally, and the coils are made to revolve at the very extremity of the magnet. The magnetism of the bar induces an instantaneous current in the coils of wire at their approach and at their departure from the magnet, and thus there is produced a to-and-fro current.

tator already referred to, the currents are turned in one direction, and so transient are the interruptions that the current is practically continuous. It is in a high degree probable that the improvements in this direction will be utilized in the instruments for the medical applications of electricity in the future (Fig. 44).

FIG. 45.



Brush dynamo-electric machine. This machine is driven by steam-power. Several powerful magnets are used, and the armature revolves between the poles. At first only a feeble current is produced, but it passes around the coils of the electro-magnets, increasing their magnetism. Consequently the magnets act more powerfully on the revolving coil, causing a stronger current, and this, in turn, strengthens the magnet. Hence the power of the machine goes on increasing with the speed. It is used for electric lighting, etc.

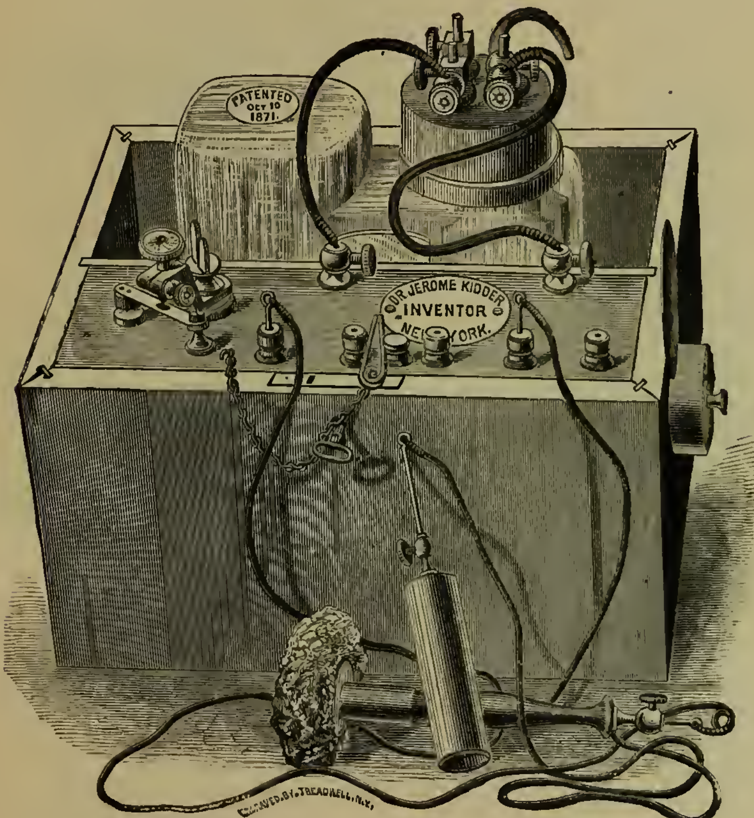
CHAPTER VII.

ELECTRO-MAGNETIC AND MAGNETO-ELECTRIC BATTERIES FOR MEDICAL USE.

Having set forth the principles on which the construction of faradic instruments rests, it is necessary now to enter into some details in regard to their form and the mode of managing them. It would be invidious to decide as to the relative merit of the manufacturers of these instruments. There are now to be obtained excellent instruments from the chief dealers, but the arrangement of the hammer by which very slow or rapid interruptions can be effected is very important, and this point should be looked to in the selection of an instrument (Fig. 40). Besides the gradation in the interruptions, batteries should possess means for regulating the force of the current from a faint, scarcely perceptible tingling to the most intense burning pain. The elements should be portable and not spill when carried about, and there should be an arrangement for lifting the zinc out of the fluid when not in use (Fig. 40). The Grenet cup fulfils these conditions, and this, or some modification of it, is now chiefly used. Kidder has invented a "tip cup," which is so arranged that when the battery is not in action the cup is turned over and the fluid flows into a diverticulum (Fig. 46). Every faradic battery should have a movable cylinder for modifying the strength of the current, and should furnish the extra and secondary current. The "primary current," so called, is reinforced by induction between the turns of the coil and the core of soft iron, and is chiefly the "extra current" of Fara-

day. Those who suppose that the primary current is a galvanic current derived from the cell, or cells, are

FIG. 46.



Kidder's faradic battery, with "tip cup."

greatly deceived, and yet there are many who entertain this notion, misled by the term.

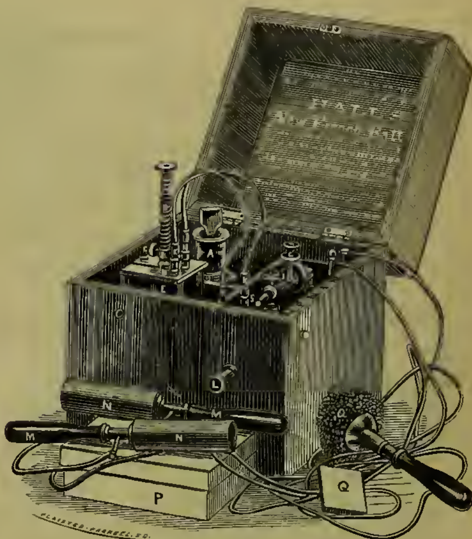
A most convenient and portable battery is that of Gaiffé. It is in the shape of a post 8vo. book, and may be carried in the pocket. The zincs are acted on by the bisulphate of mercury, and the usual coil, rheotome, cylinder, and electrodes are contained in the box. This

arrangement furnishes a current of sufficient strength for many purposes, and is especially adapted to outside

FIG. 47.

Flemming's faradic battery.

FIG. 48.



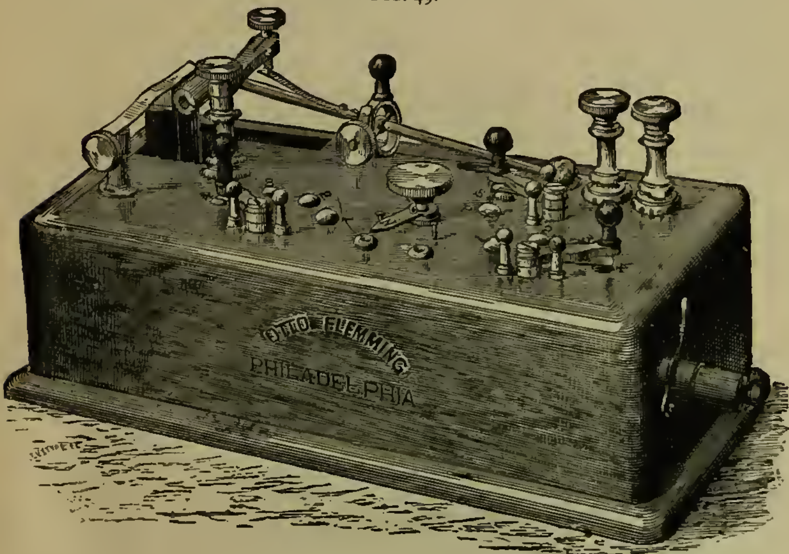
Hall's faradic battery.

practice (Fig. 50). In the purchase of a faradic instrument, the reader should bear in mind the importance of an arrangement for slow interruptions. Although the screw of the Neef's hammer permits some variation in the number of interruptions, it does not admit of the slow breaks in the circuit effected by the fork and hammer of the Galvano-Faradic Company, or the ring and lever arrangement of Flemming. The importance of this point consists in the fact that rapid interruptions throw the muscles into a tetanic state, whereas, by the other arrangement, distinct muscular contractions, with intervals of complete relaxation, are assured.

Besides the battery, certain accessories are required. Wires of sufficient length for ready application of the

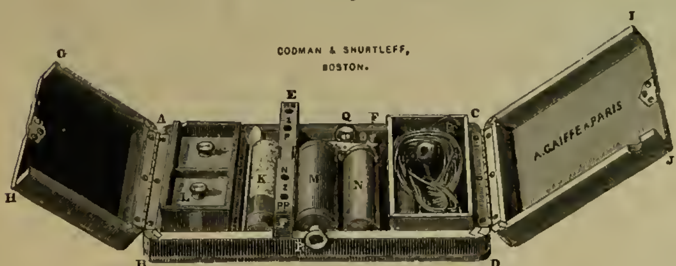
electrodes, and a variety of electrodes are necessary. The wires should be of copper of considerable thickness, and should be well insulated. The need of preserving the pliancy of the wire has led to the use of silk and

FIG. 49.



Faradic apparatus for office table.

FIG. 50.

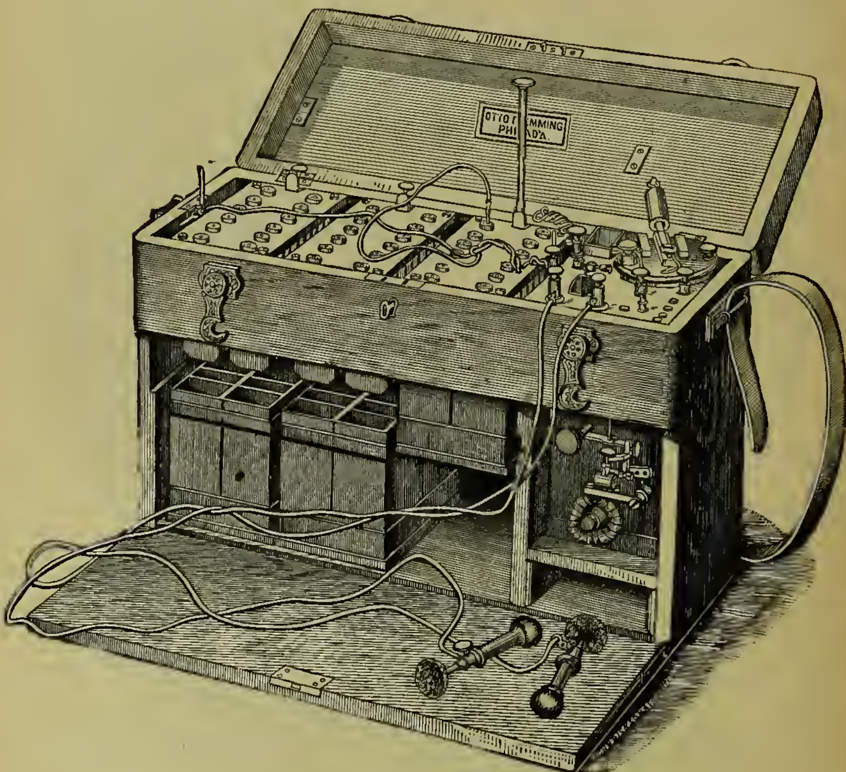


Gaiffé's sulphate of mercury pocket battery.

woollen materials for insulation, but when these become wet they no longer insulate, and they usually wear out very soon. On the whole, the best material is telegraph

wire coated with gutta-percha. This is sufficiently flexible, and the coating can be removed with the knife when connections are to be made. The best electrodes are carbons of various forms, having hard-rubber handles. The carbons are covered with soft sponge. As these

FIG. 51.



Combination battery.

sponges should be frequently renewed, certainly daily when they are much used, reef sponge should be selected, both on account of cheapness and superior softness. Over the sponge should be tied some gauze. When general electrization by the faradic current is to be prac-

tised, large electrodes should be used, but, when nerve or muscle applications are to be made, the electrodes must be small. For isolating, and for application to individual muscles, Duchenne's electrodes are very useful. They are olive-shaped and curved to facilitate application by a single hand. There are electrodes for the phrenic nerve, for the larynx, rectum, bladder, vagina, uterus, and other organs, a broad copper plate for the feet to rest on, a brush for the skin, and needle electrodes for electrolysis. The various forms will be again referred to in connection with the particular purposes for which they are used.

All the principal dealers now furnish combined galvanic and faradic combinations in one box, intended both for office use and for outside practice. They are arranged to be transported without spilling the fluids. Although these are excellent in their way, great annoyance is caused by the difficulty of keeping them in good working order. The elements require frequent changes to keep them active, and the connections are apt to become broken by corrosion of the metals. Only those should undertake the care of complex arrangements of this kind who are familiar with principles and the mechanical details (Fig. 51).

CHAPTER VIII.

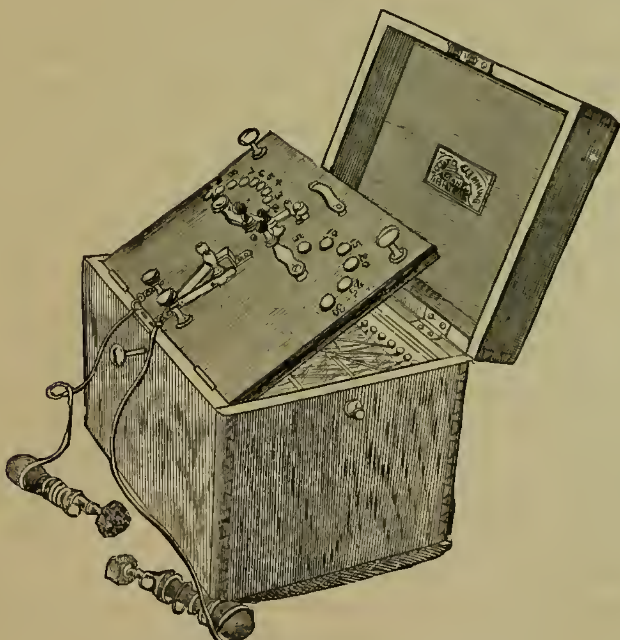
CARE OF BATTERIES, GALVANIC AND FARADIC: MANIPULATION.

It cannot be too strongly impressed on those who purpose providing themselves with electrical apparatus, that both galvanic and faradic appliances are necessary. It must also be insisted on, that large elements with two fluids furnish a current capable of better therapeutical results than small elements with a single fluid. The former, also, require much less care. The Siemens and Halske cup, and the gravity battery, which are the best for medical purposes, require but little attention after they are once put up. A few crystals of sulphate of copper, and a little water to supply the loss by evaporation, need to be added from time to time. The portable battery of one fluid requires a great deal of attention. When freshly charged, the action at once attains the maximum, and then declines. There are, therefore, considerable variations in the tension from time to time. As soon as the application is ended, the elements should be raised out of the fluid. As the fluid rapidly changes and loses strength, it should be often renewed,[1] the elements washed, the zincs amalgamated, and the carbons occasionally baked. After every immersion the elements should be washed and dried. The commutator

[1] In a battery of Smee's elements, the exciting fluid consists of sulphuric acid, diluted—one part of the acid to fifteen parts of water. The fluid of the zinc-carbon batteries consists of sulphuric acid and bichromate of potassium—two ounces of the acid, one ounce of bichromate of potassium, and sixteen ounces of water. The water and acid should be mixed first, and, when cold, the bichromate of potassium added.

and current selector of the portable battery is apt to become oxidized, and hence the communications fail. All of the connections should be rubbed with emery paper to keep them bright. If the smaller Leclanché cups can be procured, and the operator is so situated that he can send the elements to the dealer for the necessary repairs, a combination of twenty to forty of these cups will be the best portable battery, especially if it is to be placed in the hands of the patient (Fig. 52). The cups being sealed, and continuing in action for a

FIG. 52.



Portable Leclanché as made by Flemming.

long time, will require no attention. A battery of this kind obviates the very serious objections above expressed in regard to the portable batteries now in use, and will need only the necessary supervision of the wires and current selector with their connections.

Batteries should be protected from dust, grease, and moisture. A small particle of dust interposed between conducting parts, or a little grease, may interrupt the current. If the battery does not work, the fault may be at various points. It may be in the pole-wires or connections with the electrodes. These should be carefully examined. The fault may be on the pole-board. Does the needle of the galvanometer move when the wire of the positive electrode is brought in contact with the post of the negative, and not when the negative is brought against the post of the positive; then the failure is in the negative electrode or its wire. If the test is reversed, the failure is in the positive. Next, each part of the pole-bard, the stops, the commutator, rheostat, interrupter, etc., should be examined in turn; then the connections of the wires leading from the cups to the buttons on the pole-board; and, lastly, the communications between the cups, until the fault is found. If the galvanic battery has been completed, how determine the position of the poles—which is positive, which negative? Prepare some starch mixture, and add to it a few crystals of iodide of potassium; when the electrodes are immersed in this fluid, iodine appears at the positive pole, forming the blue iodide of starch. It has already been pointed out that the zinc surface in the battery, where the chemical action is going on, is positive; but that the current outside passes from the copper to the zinc, whence the zinc is the negative pole, and the copper the positive. If the battery is in working order, how determine the strength of the application? The number of cups brought within the circuit is the first rough mode. Theoretically, the degree of deflection by the needle of the galvanoscope measures the strength of the current, but in practice this is found to be very inaccurate. The

best test of the strength of the current, for very delicate applications, in the absence of an absolute galvanometer, is the tongue of the operator; and, for the coarser, the hand. If, however, the operator is provided with an absolute galvanometer, the application of current strength becomes more precise—the number of milliwebers being read off the scale, as degrees on a mercurial thermometer. The usual strength of application ranges from 1 to 20 milliwebers. When the number of elements is the guide to the strength of application, it will be convenient to remember that the Daniell has an electro-motive force of one volt; the zinc-carbon (Stöhrer, Grenet, etc.) of 1.5 volts, and the Leclanché of 1.3 volts. Roughly, 3 Daniell's are estimated to be equal to 2 Leclanché. Having decided on the number of milliwebers to apply, it is far better to obtain them by using a large electro-motive force (volts), and interposing sufficient resistance (ohms). The current thus obtained will not vary in tension, and, if changes in strength are required, resistances may be taken out or added, as may be necessary. Especially ought the strength of the current be carefully determined before applying galvanism to the face or head. The size of the electrode greatly influences the merely local effect of the current. If a large volume of galvanic electricity is made to traverse a small electrode, it is introduced into the skin in a very condensed form, and therefore causes a severe burning pain, which, if distributed over a larger area, would produce but little effect. It need hardly be asserted that metallic electrodes, conducting rapidly, are more irritating than sponge-covered electrodes. Formerly the induction machines were supplied with a brass cylinder electrode, the only mode of application then practised consisting in holding the electrodes in the hands.

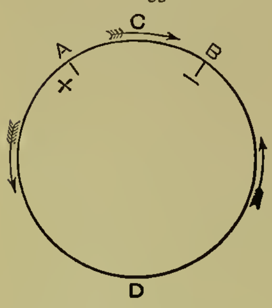
Strange as it may appear, very little was known of moistened electrodes up to the time of Duchenne de Boulogne. The importance of the suggestion proved to be very great, for the skin offers a strong obstacle to the passage of electricity, owing to the dryness of the epidermis. The conductivity of the tissues in general is directly as their degree of moisture. Much of the electricity is converted into heat in the attempt to traverse the dry epidermis, and hence does not reach the parts beneath. By thoroughly moistening the epidermis by wet sponge electrodes, the conductivity of the skin is so increased that the nerves and muscles are readily reached. On the other hand, if it be desired to confine the action to the skin, as is sometimes the case, it is thoroughly dried, and also dusted with some drying powder. In some cases of neuralgia, electrical excitation of the skin has a good effect, but the current must be prevented passing through the skin by the expedient above described.

It is a fundamental principle that *electrical applications must be made to the affected part.* This fact, which we also owe to Duchenne, was emphasized by him in the title of his work, *De l'Electrisation Localisée.* To this principle may be added the further one—electrical applications should also be made to the parts where decided symptoms are experienced. Certain terms have been established by usage to designate the kind of application practised. Thus when the poles are kept in a fixed position, the applications are said to be *stabile*, and when they are moved over the surface, *labile.* The difference between them is considerable; for, while the stabile applications are constant and uninterrupted, the labile are rapidly interrupted in proportion to the rate of movement over the surface. When the current descends from the centre to the periphery, it is called a *direct* or

descending current. If the current pass in the opposite direction, it becomes the *inverse* or *ascending*. *General electrization* is a term employed to designate a method of application in which the whole of the surface in turn is acted on. Galvanism or faradism may be so applied, but the method is advocated chiefly by Beard and Rockwell, who apply the faradic current, the feet resting on a copper plate connected with either the anode or cathode, whilst the other pole is rubbed over every part of the body. General electrization may also be accomplished by static electricity. The patient stands on an insulated stool, one hand in contact with the prime conductor of an electrical machine, and is charged with positive electricity. Sparks may be drawn from any part of the body. General electrization may also be accomplished by the *electric bath*. The patient is immersed in water, which should be either slightly acidulated or saline to increase its conducting power. The poles are simply connected with the water. So great is the resistance offered by the water to the passage of electricity, that but little, if any, effect is produced by even powerful currents. Charlatans who apply this method impose on their ignorant clients by connecting the electrodes with some part of the patient's person, but when this is done it is no longer an electric bath. Under any circumstances, applied as completely as can be, the electric bath is a very inferior application, and violates the canon which requires applications to be made to the affected part. The same remark is true of general electrization. It is undeniable that patients have improved under a course of general electrization, but how much of the benefit is due to mental influences does not appear. We know that extraordinary results have been achieved by agencies which simply impressed the imagination.

Local applications are intended to affect muscles and nerves. A muscle may be acted on directly or indirectly. Thus, when the muscle is directly reached by moistened electrodes placed over it, the application is designated *direct.* If one electrode is placed over the motor nerve and the other on the belly of the muscle, the application is said to be *indirect.* The direction taken by the current is determined by the position of the electrodes and the character of the tissues traversed. The current, in large part, passes by the most direct route from one electrode to the other, but not entirely so; much of it passes by the lines of least resistance. If the electrodes are placed on the arm, as indicated in the figure, the current affects the muscles of the arm, because of the diffusion of the current. If the electrodes are still more approximated, the diffusion of the current takes the direction indicated in this schematic representation (Fig. 53), and the muscles are acted on accordingly. By Duchenne, the contraction of the muscles occurring at remote points was referred, not to diffusion of the current, but to reflex action, but he was mistaken in this assumption. The degree of diffusion of the current is affected somewhat by the size of the electrodes—the larger the electrodes the more wide the diffusion of the current. The electrodes may be never so small, and yet some diffusion will take place. The force of the current is also concerned, for the stronger the current the more diffusion. Many of the phenomena of eiffusion are due to "derived currents" (E. Onimus et Ch. Legros[1]). They are easily

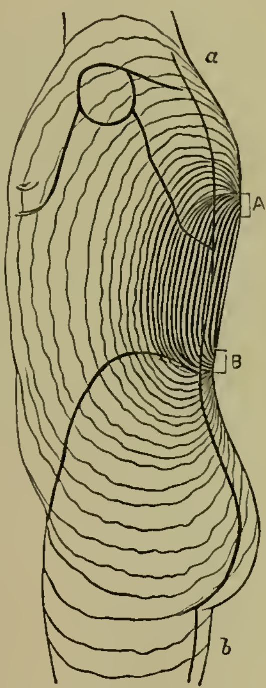
FIG. 53.



[1] Traité d'Electricité Médicale, Paris, 1872.

explained by reference to the subjoined diagram (Fig. 53): Give a circuit formed by A, B, C, and D. Let the positive pole be placed at A and the negative at B. The chief part of the current will take the direction from A by C to B; but at the same time there will be a derived current passing from A by D to B. The more decided the resistance between A and B, and the greater distance between them, the more considerable the volume of electricity from A to B by D. The influence of derived currents is shown in the widespread reactions which ensue when the poles of the battery are placed at certain points on the body. When a strong current is passed through the electrodes, one on the neck and the other on the lumbar region, a metallic taste is experienced in the mouth, there are flashes of light from the eyes, and a rumbling noise is heard in the ears. These facts are illustrated in Fig. 54, taken from Erb. If the positive electrode is applied at A, and the negative at B, the current diffuses as indicated by the curved lines, through the body. The major part passes by the nearest route from A to B, but more or less deflected to follow the lines of least resistance. The derived currents are from A to a and from B to b, outside of and beyond the interpolar. The more widely separated the poles, the greater the diffusion. Secondary currents, about which little is known, however, are produced on the opening and closing the galvanic current.

FIG. 54.



PART II.

ELECTRO-PHYSIOLOGY.

CHAPTER I.

ANIMAL ELECTRICITY.

In certain fishes there exists an apparatus for generating electricity not unlike the cups in a galvanic combination. These fishes are, the electric eel (*Gymnotus electricus*), the electric ray (*Torpedo vulgaris*), and the electric shad (*Malapterurus electricus*). The electricity which the electric organs of these animals generate is precisely the same as that produced by galvanic combinations. The proof of this statement is afforded by the following facts: The electricity of these fishes will magnetize iron, decompose water, or a solution of iodide of potassium, deflect the needle of the galvanometer, etc. As in a galvanic battery, the electro-motive force is due to the amount of the chemical action, so in these electric fishes, the quantity of electricity produced by them is in a precise ratio to the functional energy displayed by the organs of circulation and of respiration. Both the gymnotus and the torpedo possess an electric organ composed of membranous prisms, arranged like the cells of a honeycomb, and each prism is subdivided by horizontal diaphragms into small cells containing an albuminous fluid. The diaphragms are electro-positive on one surface and electro-negative on the other, and between them is an electrolytic albuminous fluid having an acid

reaction. The electric organ of the malapterurus differs somewhat from the others in the arrangement of its cells, which are contained in a tube surrounding the fish, and extending from head to tail. This tube is intimately connected with the skin, and is divided by a membranous septum into two lateral halves.

The electrical organ of each variety of electrical fish is connected with the central nervous system by large nerves, numerous filaments being distributed to the cells. In the torpedo the electric organ communicates by four large nerves with the fourth lobe of the brain, irritation of which is followed by strong discharges of electricity. A similar arrangement exists in the gymnotus, but in the malapterurus the nerves communicating with the electric organ arise from the spinal cord, between the second and third spinal nerve roots. The activity of the electric organ is destroyed by coagulating the albuminous fluid of the cells; by chemicals which injure the nerves; by section of the nerve-trunks connecting the organ with the brain or cord; by placing the fish under the influence of ether or woorara, etc. Discharges are received by touching the fish at any point, but in the malapterurus the most powerful shocks are felt when the head and tail are simultaneously touched. The discharges of the electrical organ are also under voluntary control, and are employed for defence against enemies, and to benumb their prey. Frequent discharges exhaust the resources of the organ, and a period of repose is then necessary to enable it to recover its powers.

Although other animals are not possessed of an electrical organ, electrical currents circulate in them. Galvani was the first to demonstrate the existence of these currents, but the most important contributions to our knowledge have been made by Matteucci and Du Bois-

Reymond. As developed by the latter especially, and by the labors of Pflüger, Von Bezold, and others, in Germany, electro-physiology has reached enormous proportions, but its abstruseness has deterred all except the most zealous workers from its study. Undoubtedly the subject is undergoing a transition, and the conviction is growing that it needs careful revision with the improved knowledge and methods of research now available for the purpose. So uncertain is the condition of the subject, so doubtful the accuracy of much of the supposed knowledge, and so little available for application to medical electricity, that it will be best to give here only the slightest sketch of those facts which seem most firmly established.

Matteucci held that the electro-motive force of animal electricity is derived from the muscles, and that the nerves are mere conductors, participating in the electrical condition of muscles at the points of contact with the latter only. Du Bois-Reymond has, however, proved that there are currents in nerves as well as in muscles. The *natural transverse section* of a muscle is the base of the fibres terminating in the tendon, and the *natural longitudinal section* is the surface of the muscle. The artificial transverse section and the artificial longitudinal section are divisions of the muscle carried to any degree of minuteness, and made in the same direction as the natural sections. It is found that the direction of the current is from the natural longitudinal section to the natural transverse section—in other words, in the direction of its fibres. The same fact is true of any artificial section of the muscle. The following formula expresses these facts:—

"Each point on the longitudinal section of a muscle is positive in relation to points on the transverse section,

whether natural or artificial." This law deduced by Du Bois has been confirmed by observations on the muscles of an amputated limb of man, and on the muscles of various animals. Electrical currents are also obtained by contact with the electrodes of the galvanometer, with two points on the *same* surface, provided they are not equidistant from the median section, and that point nearest the centre is positive in relation to that point which is most remote. The same fact is true of the transverse as well as of the longitudinal section. The intensity of currents obtained from the same section is greatly less than that obtained from different sections. Acting on different muscles, it is found that the current is more intense in those muscles having the highest functional activity. Thus the muscle of the heart furnishes the most active, whilst the muscle of the intestine furnishes the least active, current.

There are currents in nerves as in muscles. A current moves from the longitudinal section of a nerve (its external surface) through the galvanometer to the transverse section, and the points which are nearest to the middle of the nervous fragment are positive in respect to those which are nearer to the extremities. The same law holds true as regards the brain. Every artificial section of the brain is negative to every point of its natural surface. During the contraction of a muscle, or during the active state of a nerve, the natural currents diminish, or indicate a negative deviation.

When a nerve, fresh and excitable, is acted on by a galvanic current, a remarkable change takes place in its condition. This change is called the *electrotonic state*, and is induced not merely by the passage of a galvanic current, but involves an actual alteration in the electrical properties of the nerves. That such is the fact is

proved by tying a wet thread tightly around the nerve, which does not interfere with the transmission of the electric current, but does entirely prevent the development of the electrotonic state. If the galvanic current moves through the nerve in the same direction as the nervous current, the intensity of the latter is increased. Whence there is developed *the positive phase of the nerve*, according to Du Bois-Reymond. The nerve current is diminished in intensity by the passage of the galvanic current in the opposite direction—whence *the negative phase of the nerve*. The electrotonic state continues unchanged as long as the current is passing, but disappears on breaking the circuit. All electrical phenomena of every kind cease when the vitality of the nerve is destroyed. The same fact is true of the muscles. Electrical manifestations decline after the death of the animal, and cease entirely when rigor mortis sets in.

The discoveries of M. Becquerel in electro-capillarity are very important. He has ascertained that electrochemical circuits are produced between two liquids separated by a membrane. That part of the membrane in contact with the liquid acting as an acid, is the negative pole, and the opposed surface is the positive pole. The different anatomical elements—cells, tubes, globules, and their liquid connections—form electro-capillary couplets. Becquerel has shown that a muscle in contact with respired oxygen is in the same condition as in presence of the blood, but the results are not exactly the same, and when the muscle is disorganized, reduced to a paste, it consumes a quantity of oxygen double that used by a muscle which is entire and of the same weight. If the intact muscle, and the muscle reduced to a paste, are placed on a plate of platinum, and another platinum plate introduced into the interior, a current is found to

pass from the interior to the exterior, as shown by the deflection of the needle of the galvanometer; the exterior is positive, and the interior negative. As the exterior is in contact with the oxygen of the air, and is oxidizable, it is a reasonable presumption that this is the determining cause of the muscular current passing from the exterior to the interior. It follows, according to this view, that electrical currents in muscles have their origin in chemical action. This view is strongly supported by the experiment in which the muscle is immersed in nitrogen or hydrogen. Under these circumstances the current passing from the exterior to the interior lessens, then ceases, and finally passes in the other direction, because of the oxidizable materials still present in the interior. Further experiments by Becquerel have shown that there exist numerous electro-capillary currents between the blood and the liquids in the muscles. In the arterial blood, oxygen is fixed in the hæmatosin by capillary affinity. That face of the capillary in contact with the arterial blood is the negative pole, and the opposed face next the muscular fluids is the positive pole.

CHAPTER II.

ACTION OF THE GALVANIC CURRENT ON MOTOR, SENSORY, AND MIXED NERVES

It will assist the reader to comprehend the action of galvanic currents on nerves, if the account of these phenomena is preceded by some observations on contraction of muscle, for it is by muscular contraction that many of the nervous actions are interpreted. Muscular tissue is composed of contractile elements, which have the power to shorten themselves when acted on by certain stimulants. This property is called *irritability*, and Hallerian irritability, because first supposed to exist by Haller. If a muscle, fresh and uninjured, be irritated by pinching, by chemicals, or by galvanism, it will at once contract, *i. e.*, shorten in its long diameter and bulge at the sides. When left undisturbed, the muscle remains entirely quiet, but when irritated, it contracts. It is not necessary that the irritation be applied directly to the muscle. Contraction will ensue in the muscle when the motor nerve supplying it is subjected to irritation. The nerve, also, possesses the property of "irritability," but no change takes place in its form or appearance when it is subjected to irritation. It may undergo some molecular modification, but the nature of this is unknown. The impulse originating in the nerve by irritation is communicated to the muscle, and contraction of the muscle takes place. The muscle-nerve preparation for demonstrating a muscular contraction consists of the gastrocnemius, with the sciatic attached, of the frog. The nerve acted on by the electrodes of an induction machine, and

FIG. 55.

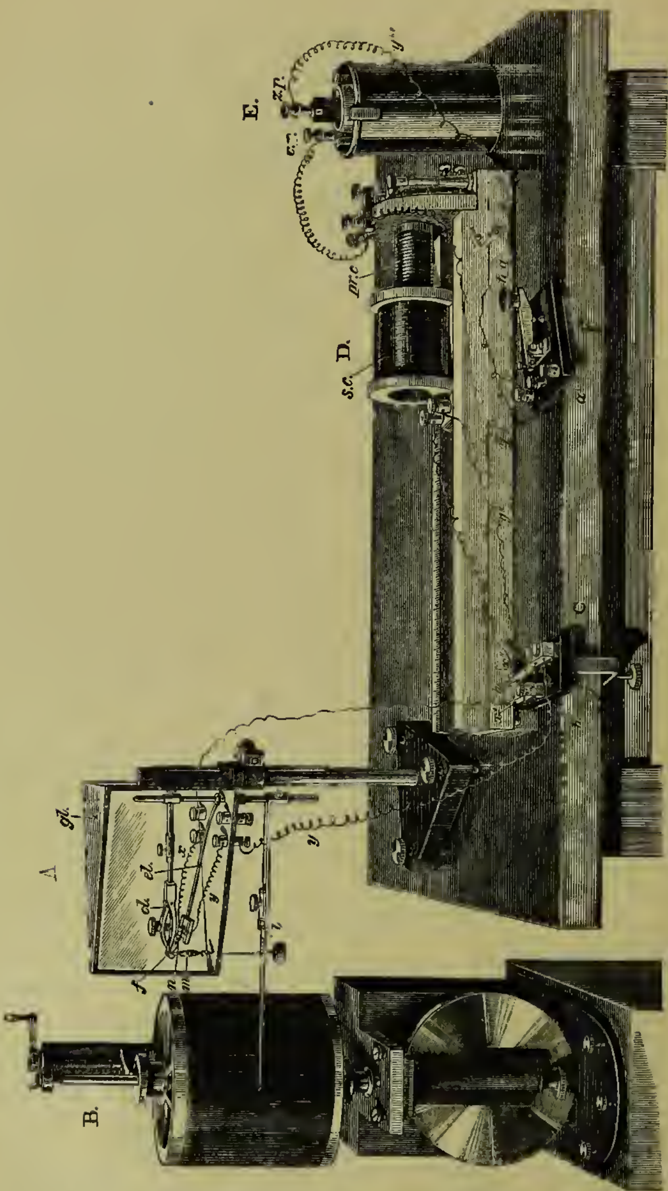


Diagram illustrating apparatus arranged for experiments with muscle and nerve.

A. The moist chamber containing the muscle-nerve preparation. (The muscle-nerve and electrode-holder are shown on a larger scale in Fig. 56.) The muscle *m*, supported by the clamp *cl*, which firmly grasps the end of the femur *f*, is con-

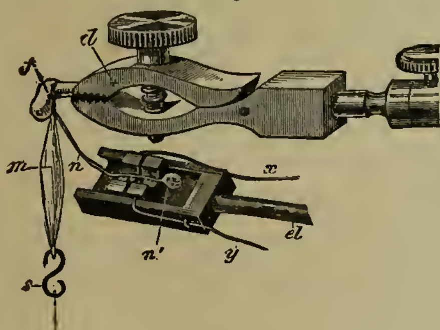
nected by means of the S hook *s* and a thread with the lever *l*, placed below the moist chamber The nerve *n*, with the portion of the spinal column *n′* still attached to it, is placed on the electrode-holder *el*, in contact with the wires *x y*. The whole of the interior of the glass case *gl*, is kept saturated with moisture, and the electrode-holder is so constructed that a piece of moistened blotting-paper may be placed on it without coming in contact with the nerve.

B. The revolving cylinder bearing the smoked paper on which the lever writes.

C. Du Bois-Reymond's key arranged for short-circuiting. The wires *x* and *y* of the electrode-holder are connected through binding screws in the floor of the moist chamber with the wires *x′ y′*, and these are secured in the key, one on either side. To the same key are attached the wires *x″ y″*, coming from the secondary coil *s c* of the induction machine *D*. This secondary coil can be made to slide up and down over the primary coil *pr c*, with which are connected the two wires *x‴* and *y‴*. *x‴* is connected directly with one pole, for instance, the copper pole *c p* of the battery *E*. *y‴* is carried to a binding screw *a* of the Morse key *F*, and is continued as y^{iv} from another binding screw *b* of the key to the zinc pole *z p* of the battery.

Supposing everything to be arranged, and the battery charged, on depressing the handle *ha*, of the Morse key *F*, a current will be made in the primary coil *pr c*, passing from *c p*, through *x‴* to *pr c*, and thence through *y‴* to *a*, thence to *b*, and so through y^{iv} to *z p*. On removing the finger from the handle of *F*, a spring thrusts up the handle, and the primary circuit is in consequence immediately broken. At the instant that the primary current is either made or broken, an induced current is for the instant developed in the secondary coil *s c*. If the cross-bar *h*, in the Du Bois-Reymond's key be raised (as shown in the thick line in the figure), the wires *x″*, *x′*, *x*, the nerve between the electrodes, and the wires *y*, *y′*, *y″*, form the complete secondary circuit, and the nerve consequently experiences a making or breaking induction-shock whenever the primary current is made or broken. If the cross-bar of the Du Bois-Reymond key be shut down, as in the dotted line *h′* in the figure, the resistance of the cross-bar is so slight compared with that of the nerve and of the wires going from the key to the nerve, that the whole secondary (induced) current passes from *x″* to *y″* (or from *y″* to *x″*) along the cross-bar, and none passes into the nerve. The nerve, being thus short-circuited, is not affected by any changes in the current.

FIG. 56.

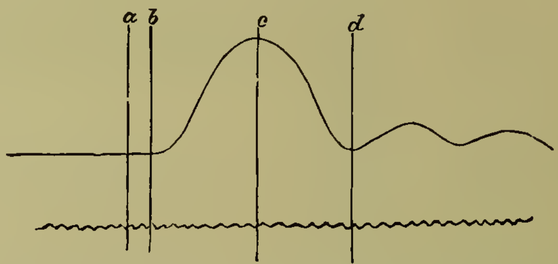


The muscle-nerve preparation of Fig. 55, and the clamp electrodes, and electrode-holder are here shown on a larger scale—the letters as in Fig. 55. The form of electrode-holder figured is a convenient one for general purposes, but many other forms are in use.

the muscle, is arranged so that its movements can be recorded on a revolving cylinder. The whole apparatus is represented in Fig. 55 and Fig. 56 (from Foster's Physiology).

A muscle-curve obtained by this apparatus has the form shown in Fig. 57. We learn from this that a mus-

FIG. 57.



A muscle-curve. *a* indicates the moment when an induction-shock is sent into the nerve; *b*, the commencement; *c*, the maximum; and *d*, the close of the contraction. (FOSTER.)

cular contraction, which seems a single movement, is made up of several. There is a distinct interval between the reception of the shock of the induction coil, and the beginning of the muscular contraction. This period, which is antecedent to any visible alteration in the muscle, is known as the latent period. Then follows the phase of contraction which is not instantaneous, but gradual, reaching its maximum, and then relaxing, the whole act occupying about $\frac{1}{20}$ of a second.

When a descending galvanic current is made to traverse a motor nerve, a contraction of the muscles to which the nerve is distributed, takes place at the closing and, under some circumstances, at the opening or cessation of the current. If there be no variations in the intensity of the current, during the whole time it is passing, the muscles remain quiet. If the current is feeble, the muscular contraction will take place at the closing of the

circuit only. Under all circumstances, the energy of the muscular contraction is greater at the closing than at the opening of the circuit.

Different reactions are obtained with inverse or ascending currents. When a motor nerve is acted on by a feeble inverse current, muscular contractions are obtained, only at the opening of the circuit, but if the current is strong, both at the opening and closing. Muscular contractions produced by galvanic excitation, are stronger when induced by a direct current.

The sensory nerves are affected by the galvanic current, not only at the opening and closing of the circuit, but during the whole time the current is passing. The ascending or inverse current, however, acts more energetically, or, in other words, excites more painful sensations than the descending or direct current.

As regards the mixed nerves, it has been ascertained that the excitability of nerves is lessened by a descending current, and increased by an ascending current. From this law has been deduced the following: a nerve whose excitability is impaired by a descending current has it restored by an ascending current, and conversely, a nerve whose excitability is increased by the ascending current has it lessened by a descending current. The excitability of nerves seems to be due to the influence of the cord as well as to the passage of an inverse electric current.

The results of galvanic stimulation of nerves is somewhat different when the nerves acted on are covered by the tissues. Thus far the laws given were deduced from direct stimulation of the nerves, the rheophores being in actual contact with them. Stimulated through intervening tissues, it is found that the most energetic contractions are obtained from the ascending or inverse current,

and at the closing of the circuit. If the influence of the cord be withdrawn, by destroying it, or paralyzing it with narcotics, the contractions which were very strong in the member traversed by an ascending current, are now very greatly diminished, whilst in the other member they are still very decided. In man, in the pathological state where the sensibility is diminished, more energetic contractions are obtained with a direct or descending current, whilst in the normal condition, and especially in those who are impressionable, the inverse or ascending current produces the strongest contractions.

When sensory fibres are excited, contractions result. Are they *reflex* or *induced* contractions? The contractions excited by an ascending current are more decided when the sensibility is intact; but when the sensibility is destroyed or greatly diminished, the contractions are very feeble, and are stronger under these circumstances when excited by a descending current. It is probable, then, that the contractions due to excitation of sensory nerves are reflex.

When a galvanic current is made to traverse a nerve, it is put into a peculiar state—the *electrotonic* state or *electrotonus*. If the current traverse the nerve in the same direction as the nerve current, the intensity of the latter is increased; if in the opposite direction, it is diminished. The two phases of this condition have been designated by Du Bois-Reymond—the *positive* and the *negative*, who explains it by assuming that a polarization of the intervening molecules takes place, just as in the transference of the current from one element to another in the exciting fluid of the voltaic cell. According to Pflüger, the passage of the current affects the nerve, causing two states: that part of the nerve in contact with the anode loses its excitability, and is hence known

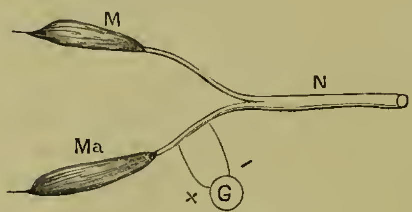
as *anelectrotonic;* the other part in contact with the cathode has its excitability increased, and is hence known as *catelectrotonic.* The anelectrotonus and the catelectrotonus exist for a short distance from the point of contact of the poles, and are increased with the augmentation of the current, up to a certain point, when they diminish and disappear. This condition of increased or diminished excitability of the nerve at the negative and positive pole respectively, may be explained in another way. When a nerve is subjected to the action of a galvanic current, its constituents capable of electrolytic decomposition must necessarily obey the laws of electrolysis; the alkalies and hydrogen will appear at the negative pole, the acids and oxygen at the positive. This is a fact in regard to which there can be no difference of opinion. Humboldt was the first to discover that the excitability of a nerve is increased by contact with an alkaline solution, and diminished by contact with an acid solution. Matteucci maintained, in accordance with these data, that the phenomena of anelectrotonus and catelectrotonus were simply due to these chemical actions, and Becquerel has arrived at the same results. Onimus and Legros oppose to this chemical theory of electrotonus, the important observations, that when the current is strong the electrotonic state diminishes and then disappears, and that anelectrotonus is induced when the electrode is separated from the nerve by the integument and fatty tissue. They conclude that neither the explanation of Pflüger and the German school nor that of Matteucci suffices, and that the phenomena in question are due to a functional modification produced by the difference in the direction of the current.

The contraction of a muscle is stronger the more in-

tense the current acting on it, but this is true to a limited extent. When decided contractions are obtained by a given current, it is useless to attempt to produce greater, for all added beyond this maximum increases the pain without causing stronger contractions. Changes in intensity of the current increase the excitability of the sensory nerves, which is the greater the more rapid the variations.

If a nerve is acted on by an electrical current as represented in the figure, the molecular change produced in it effects a modification of the same kind in the molec-

FIG. 58.



Induced contractions.

ular condition of the neighboring nerve, causing a muscular contraction as if the nerve were directly acted on. Let *M* and *Ma* represent two muscles with their afferent nerves attached, and *N* the trunk of the nerve. Let *G* stand for the galvanic element and + and — for the positive and negative electrodes. If a current from *G* acts on the afferent nerve proceeding to *Ma*, muscular contractions will be caused in *Ma;* but the change in the molecular state of this nerve, induced by the current, will affect the molecular condition of the nerve proceeding to *M*, and contractions will take place in *M* also. The contractions in *M* are designated induced contractions.[1]

If a motor nerve has been acted on by a direct current

[1] Onimus et Legros—Traité d'Electricité Médicale. Paris, 1872.

for some time, its irritability becomes exhausted, but if now it is stimulated anew by an inverse current, its excitability is restored. The muscular contractions first induced by stimulating the motor nerves by the direct current after a time cannot be produced, but if now the inverse current be employed, the contractions occur again. For an indefinite time such disappearance and such return of muscular contractions can be effected by alternation of the current direction. To these phenomena have been applied the term *voltaic alternatives*.

CHAPTER III.

ACTION OF INDUCED OR FARADIC CURRENTS ON MOTOR, SENSORY, AND MIXED NERVES.

When an induction current is applied to a mixed nerve, pain is experienced, and muscular contractions ensue in the muscles innervated by the motor filaments. Acting on a sensory nerve only, pain is caused; acting on an exclusively motor nerve, muscular contractions only follow. The direction of the current has apparently no influence in the result produced. If strong induced currents are passed through a nerve for a long time, the nerve loses its power of reacting to impressions—in other words, loses its excitability: if a motor nerve, no muscular contractions then follow when it is irritated; if a sensory nerve, no pain is then induced. The excitant action of the induced current depends on its instantaneity; hence decided muscular contractions are produced by a comparatively weak current. Its effect on the nerve is due to the sudden and rapid changes in the molecular condition. There is a limit, however, to the

effects due to the rapidity of the molecular changes, for if the action is too rapid, there is not time for the molecular changes to take place, when, of course, excitation is not produced. Rapid excitation of a motor nerve induces tetanic contractions of the muscles, during which relaxation does not occur at all. Slow interruptions, on the other hand, permit distinct contractions and relaxations of the muscles to take place—whence it follows that the latter are closely imitative of the physiological actions.

CHAPTER IV.

ACTION OF GALVANIC AND FARADIC ELECTRICITY ON THE SYMPATHETIC AND VASO-MOTOR SYSTEMS.

Previous to Bernard, Petit, Read, and others, had made some observations on the functions of the sympathetic system, but the present condition of our knowledge is chiefly due to Bernard. He ascertained that when the cervical sympathetic is divided a great afflux of blood takes place on that side of the head, because of paralysis of the vessel's walls, and that in consequence of this afflux a considerable augmentation of the temperature and sensibility results. It was next ascertained that if the cephalic extremity of the divided nerve be galvanized or faradized, the symptoms due to division of the nerve disappear entirely; the vessels contract again, the abnormal heat subsides, and the exalted sensibility declines to normal.

As will be presently made apparent, there are great differences in the effects of the faradic or induced current and the galvanic in respect to their action on the sympathetic. If an induced current is applied directly

to the cervical sympathetic, the following phenomena ensue: the pupil dilates, the globe of the eye projects forward, the bloodvessels of that side of the head contract, and the temperature falls below normal, the production of tears is lessened and the cornea is dry, etc. In man, applied in the ordinary way, the nerve covered by the tissues, electro-magnetic and magneto-electric currents and static electricity have but little influence on the sympathetic, whereas very mild galvanic currents act decidedly.

It is necessary to distinguish between the non-striated and striated muscular fibre, as regards the mechanism of contraction. In the striated or voluntary muscular system the contraction of the muscle occurs as a whole, and by one effort; but in the non-striated, it is composed of two acts—one of distinct and undivided contraction, the other of a vermicular motion. A typical example of the contractions taking place in the non-striated muscles, is afforded by the vermicular movements of the intestines. The contraction of these muscles is really reflex; as the intestinal contents come to a part of the canal, an impression is made on the filaments of the sympathetic, and this impression is transmitted to the ganglia presiding over these movements; an impulse originating in the ganglia is reflected over other filaments to the muscular fibre, which is thrown into action, but the action is, in the normal state, not spasmodic and in the whole muscle, but in each part in turn, producing the vermicular motion. The same mechanism exists in the bloodvessels. As each impulse of the blood column reaches successive portions of the vessel, a reflex contraction ensues, and thus from the beginning to the end of the vessel contraction of each fibre goes on in turn—the whole movement vermicular. It results

from the difference between *spasmodic* and *vermicular* contractions, that the former, by suddenly closing the vessels, cut off the blood supply, and the latter, by promoting the normal movements of the vessel walls, increase the amount of blood passing in a given time. Induced or interrupted currents, by causing spasmodic contraction, diminish the flow of blood, or arrest it entirely. As has been stated, the direct application of the faradic current to the superior ganglion of the sympathetic, causes strong contraction of the vessels, diminution of temperature, etc. On the other hand, the *continuous galvanic current* contributes to the activity of the circulation, re-establishes it when arrested, and elevates the temperature.

Although the general opinion is that the direction in which the current is passing has but little, if indeed any, influence over the result, the experiments of Onimus and Legros seem conclusive. They show that the direct or descending current increases the vermicular movements, and augments the amount of blood passing to a part, and that the inverse or ascending current lessens the flow of blood by diminishing the vermicular movements,[1] etc.

[1] Op. cit., p. 185.

CHAPTER V.

ACTION OF GALVANIC AND FARADIC ELECTRICITY ON MUSCLE —STRIATED AND NON-STRIATED.

Striated.—The existence of a distinct endowment in muscular tissue, known as irritability—Hallerian irritability—or the power to contract on the application of stimuli, has been already set forth. The action of motor nerves on muscles has, also, been explained. We have, however, now to consider the behavior of muscular tissue when acted on directly by the different forms of galvanic and faradic currents. That a muscle can be stimulated to act independently of the nerves was first actually demonstrated by Bernard, who secured the physiological separation of the nerve by the use of woorara, which paralyzes the end organs of the motor nerves, leaving the muscle intact.

When a galvanic current is applied directly to a muscle, it contracts at the opening and closing of the circuit. Whilst the current is passing, the muscle is quiet. This fact is, however, not without exceptions. Contractions do take place at times when a strong current is passing, or when there are decided variations in the tension of the current. The contraction produced by closing the circuit is stronger than that caused by opening the circuit, and this is true quite irrespective of the direction of the current.

When a very powerful current is sent through certain nerve trunks, tonic contractions may occur in the group of antagonistic muscles. For example, when the median nerve is acted on by such a current, contraction will

take place in the extensors of the hand, and will continue as long as the current is passing, but will immediately cease on opening the current. To these contractions was given the name *galvano-tonic*, by Remak, who first described them. These phenomena have given rise to much discussion. By many they are regarded as reflex, and produced by the strong irritation of the nerve. Onimus and Legros, who have thoroughly investigated the question, maintain that such galvano-tonic contractions are genuine, although they do not approve the theories of Remak. The direction of the current, they hold, is important. Certain muscles, especially those of the larynx and pharynx, readily pass into galvano-tonic contractions, when the galvanic current is applied to the neck, one pole resting on the hyoid bone, for example.

When a muscle is acted on by a faradic current, it is thrown into strong contraction. If the interruptions are rapid, the contractions do not cease, and the muscle is tetanized. If the action is kept up, the muscle becomes fatigued, and finally loses its irritability and passes into a state of cadaveric rigidity. This condition of fatigue may be due to the persistent excitation of the muscle, or to the mechanical work accomplished by it in its contractions. This rigidity is probably due to the solidification of *myosin*, an albuminous material found in muscle, and which, coagulating after death, causes post-mortem rigidity. When the muscles are fatigued, and their excitability diminished by prolonged excitation with the faradic current, their functional condition may be quickly rehabilitated by passing a continuous galvanic current through them. If faradic currents are not too long applied, and are not too strong, the functional activity and nutritive condition of the muscles is improved by them. The increased activity of the mus-

cle, when stimulated by the faradic current, causes a rise of temperature in the muscle, which may be readily measured. This rise of temperature is due simply to the increase in the oxidation processes—to the consumption of oxygen and production of carbonic acid.

The study of the action of muscles, especially those of the face, forearm, and hand, has led to some important discoveries. We owe these studies especially to Duchenne. The method of Duchenne consists in the use of his electrodes, so placed that a single muscle can be acted on separately, and its function studied. Favored with a case of anæsthesia of the trigeminus, he was enabled to examine deliberately the action of the various muscles concerned in physiognomical expression, and has enlarged our knowledge of their action. Darwin has made, in his Anatomy of the Expressions in Man and Animals, large use of these observations by Duchenne. The observations of Duchenne, although of great importance, are chiefly of anatomical interest.

The examination of muscle and nerve reactions by the *polar* method has been proved to possess distinct advantages. The response of muscle to faradic stimulation is called *faradic excitability*, to galvanic stimulation *galvanic excitability*. When muscular contractions are produced by stimulating the muscle directly, the method is designated *direct excitation*, and when by stimulating its motor nerve, *indirect excitation*. The cathode or negative pole of the faradic current should be used for excitation when it is placed on the nerve or muscle to be acted on, whilst the anode or positive pole is applied on some indifferent point.

When the galvanic current is used for developing the excitability of nerve or muscle, one pole, which may be the anode or the cathode, is the exciting pole, whilst

the other is put on some indifferent place, preferably the sternum, according to Erb. In the normal condition excitation of nerves and muscles produces certain reactions, which are hence known, when expressed in symbols, as the *normal formulæ*. When the current is closed by the application of the cathode to the part to be excited, it is called cathodal closing, or CaCl, or the German term KaS (*Schliessung*, closing). When the current is opened or broken by the cathode, it is called CaO, cathodal opening, or, in German, KaO (*Oeffnung*, opening). On the other hand, when the current is closed by the anode, the terms used are AnCl, or, in German, AnS. The phrases for anodal opening correspond, AnO, the same in German. For a muscular contraction, the symbol Co, or the German Z (*Zuckung*, contraction) may be used. Z′ (a capital Z accentuated) means in the German works a stronger contraction; z (a small z) a much weaker contraction; and Te a tetanic contraction.

Much confusion now exists about these terms. Dr. Buzzard, an eminent neurologist of London, proposes to employ the German modes of expression, for the sake of uniformity. In the first edition of this work I employed the English equivalents, but on the whole, it seems to me, on further reflection, better to familiarize ourselves with the German expressions. As we owe to Brenner, Erb, Ziemssen, and other Germans, the introduction and development of the polar method, it would be ungracious to ignore their symbols. The adoption of these expressions generally will obviate the confusion.

The cathode or negative pole has greater excitant power than the anode, and causes contraction chiefly on closing the circuit, whilst the anode causes contraction chiefly on opening the circuit.

The results of stimulation of motor nerves by the poles are expressed in three formulæ: In the *first grade* the weakest current which will cause a contraction is a cathodal closing contraction, KaSZ (Ka, cathode; S, Schliessung, closure; Z, Zucking, contraction), and no contraction can be effected by the anode.

In the *intermediate grade* the current is one in which the cathode causes stronger contraction on closure, but no contraction on opening, KaSZ′, whilst the anode causes slight contractions both on opening and closing, AnSz and AnOz.

In the *highest grade* the current is one that causes a tetanic contraction on cathodal closing, and a feeble cathodal opening contraction, KaSTe, KaOz, whilst on anodal opening and closing decided contractions occur, AnOZ, AnSZ.

Such are the normal formulæ to be obtained from nerves accessible for galvanic excitation. The same are true of the muscle, for, as has already been stated, the muscular contraction is the same, whether the stimulation be *direct* or *indirect*. It is evident that the reactions to galvanic stimulation are largely affected by the current strength, and as the formula are constant for the different degrees of excitation, we are provided with an exact method.[1]

In disease the normal formulæ may be variously altered.

Non-striated.—When the organic muscular fibre, non-striated, is acted on by a galvanic current, contraction does not ensue at once and spasmodically, as is the case with striated muscle, but a slow movement begins after the stimulus, and is slowly propagated from muscular fibres first stimulated to succeeding ones, and when the

[1] Handbuch der Elektrotherapie, op. cit. p. 81.

contraction reaches its maximum, a gradual relaxation ensues, and in regular order. The movement is vermicular. The difference in the mode of contraction of the two kinds of muscle consists in the rate of contraction, and the propagation of the impulse to all parts of the same system of fibres. As regards the rate of contraction, the iris is an exception to organic muscular fibre generally, in that, when stimulated by the galvanic or faradic currents, contraction at once takes place, and ceases when the current is broken. The pupil is made to dilate or contract as the radiating or circular fibres are stimulated. The longitudinal and circular fibres of the œsophagus, stomach, and intestine are made to contract by both forms of electrical stimulation. The spleen also contracts, if directly stimulated by the contact of the electrodes; but the spleen in the human subject will only act on very powerful stimulation. The action of galvanism and faradism on the vaso-motor system has already been discussed.

CHAPTER VI.

ACTION OF GALVANIC AND FARADIC CURRENTS ON THE CEREBRO-SPINAL AXIS.

To obtain definite reactions from the brain, by galvanic or faradic irritation, was long considered impossible. The more recent investigations have, however, not only demonstrated the electric excitability of the brain, but have opened up a new field of speculation and of scientific inquiry, by localizing function, by establishing the areas of certain "cortical centres," and by connecting the basal ganglia with definite motor and sensory func-

tions. The dura mater under normal conditions, and the cerebral cortex, are without sensibility. The localization of the cortical functions has been much advanced by the labors of Leyden, Fritsche and Hitzig, Ferrier, Nothnagel, and others. As, however, these investigations are not connected with the inquiry above us, we pass them over, despite their great interest and scientific value.

Can the brain be affected by electrical currents from the exterior? The only form of electricity which acts decidedly on the brain from without is the galvanic. Faradic currents are confined to the external tissues chiefly, and in small quantity penetrate to the brain itself. Erb made the first satisfactory demonstration, which proved the passage of the galvanic current through the substance of the brain, when the electrodes were applied at opposite points on the scalp. As the conductivity of tissues depends on the amount of water which they contain, and as numerous foramina for the passage of nutrient vessels and nerves exist, there is no insurmountable obstacle to the passage of the current through the brain. When the electrodes are placed on the mastoid processes, or one on the forehead and the other on the occiput, flashes of light, a metallic taste, and vertigo are produced, especially at the opening and closing of the circuit. These phenomena are due to the action of the current on the cerebral circulation, and to derived currents, which stimulate the nerves of special sense. On the other hand, Althaus maintains that the symptoms produced by the passage of a galvanic current through the brain are due to the excitation of the filaments of the fifth nerve. In a case of anæsthesia of the fifth coming under his observation, none of the usual phenomena of galvanic excitation of the brain could be

caused; hence he concludes that excitation of the fifth nerve causes a reflex disturbance of the cerebral functions.

As respects the action of electricity on the spinal cord, Erb[1] maintains that "the experiments on stimulation have produced few results of consequence," and that "it is still a debated question whether the substance of the cord is excitable or not, and whether all the phenomena of excitation may not be referred to irritation of the nerve roots." With the expression of these doubts, we proceed to give the results which have been obtained by direct excitation of the cord. When a galvanic current is made to traverse the spinal cord, bilateral muscular contractions and pain are produced. As a rule, the ascending current causes more decided contractions than the descending, and maintains the contractions longer. During the passage of a descending current, no form or strength of peripheric excitation will induce reflex actions. The inverse currents produce the same effect, but in general they give rise to a series of contractions in the inferior members, and augment the reflex actions. When the ascending current is passing, peripheric irritation does not cause reflex actions. It is hence concluded—

"The descending current applied to the cord acts directly on the motor nerves and not by reflex action;

"The ascending current augments the excitability of the cord, but affects the motor nerves by reflex action; the contractions determined by it are stronger, the greater the excitability of the sensory nerves and of the spinal centre, and the action on the motor nerves becomes feebler as the sensory nerves and the cord decline in excitability."

[1] Ziemssen's Cyclopædia, vol. xiii.

It follows from these conclusions that the sensory nerves lose their properties more rapidly and are restored more slowly than the motor.

In the spinal cord there exist centres of the sympathetic system. From the fifth cervical to the tenth dorsal is a region of the cord, electrical excitation of which is followed by dilatation of the pupil. An impulse originating in the cord is propagated to the cervical ganglia of the sympathetic, and referred to the radiating fibres of the iris. This region is known as the *cilio-spinal region*, and was so named by Budge and Waller, because filaments of the sympathetic system, having connection with those innervating the iris, originate here. A similar centre, governing the lower rectum, bladder, vasa deferentia, etc., has been discovered by Waller in the lumbar part of the cord, and is known as the *genito-spinal.*

CHAPTER VII.

ACTION OF GALVANIC AND FARADIC CURRENTS ON THE PNEUMOGASTRIC NERVE AND HEART.

It is well known that when a strong current is passed through the pneumogastric, the action of the heart is arrested in the diastole. A weak current, however, increases the rate and energy of the cardiac movements. When the nerve is divided, no effect on the heart is produced by galvanization of the upper extremity; but if the current is strong, the movements of the respiratory organs are arrested during inspiration. Cessation of the galvanism suffices to restore the function of respiration, which goes on as before, except somewhat more rapidly. Besides this effect on respiration, galvanization of the upper portion of the divided pneumogastric affects the production of sugar, which is found in the blood, bile, and cerebro-spinal fluid, and lessens materially, and probably arrests, the secretion of urine. Galvanization of the lower extremity of the divided nerve does not arrest respiration, but does stop the heart in the diastole.

Faradization of the pneumogastric causes an arrest of the intestinal contractions, and a lowering of the tension. When the nerve is divided, electrization of the inferior extremity has no influence on the intestine, but electrization of the superior portion of the divided nerve has the same effect as faradization of the undivided nerve (Onimus et Legros, p. 655). It is a remarkable fact that stimulation of the vagus produces the opposite effect on the stomach from that caused in the intestine.

Galvanic currents applied to the pneumogastric exert but little influence on the intestines, but have decided effects on the stomach. A descending current acting on the right or left nerve suspends the contractions of the stomach. When the galvanic current acts on the inferior portion of the divided nerve, the result differs according to the direction of the current; the ascending current has no effect; the descending current causes an immediate arrest of the stomach contractions. Vomiting is caused by the induced current; a quiescent state of the stomach by the galvanic current.

An induced current applied directly to the intestines causes contractions at the point of contact of the poles, but between the poles the parietes of the intestine are relaxed. Continuous currents abolish peristaltic movements, and lower the tension if the current acts in the direction of the normal movements, but increase the tension if acting in the contrary direction. Electrization of the cord by continuous currents increases the peristaltic movements very notably at the time of their application. Currents of induction increase the tension without determining peristaltic movements. Continuous currents acting on the splanchnic nerves give rise to peristaltic action. When the interrupted current acts on the pneumogastric, dilatation and immobility of the intestine are caused. Moderate continuous currents acting on the pneumogastric affect the intestines slightly, and arrest the contractions of the stomach.

CHAPTER VIII.

ACTION OF ELECTRICITY ON THE SPECIAL SENSES.

The galvanic current alone is adapted to stimulate the organs of special sense. Each organ is excited by stimuli to functionate in accordance with its own properties.

When a galvanic current is applied to the eyes, if at all strong, vivid flashes of light are experienced. A current from one or two elements is sufficient to develop this reaction. The flashes are brightest and of longest duration when produced by cathodal closing (KaS), that is, when the circuit is completed after putting the negative pole or cathode in position. The minimum effect is produced by anodal opening (AnO). The reaction being produced chiefly at the opening or closing of the circuit, the stimulation of the retina is probably by *derived currents.*

Brenner maintains that the eye reacts characteristically by the polar method, and that various modifications of the color sense, of light perception, etc., are thus produced. Into these speculations, however, it seems hardly necessary to enter. This organ is so sensitive that galvanic currents must be applied about the face and eyes with caution. Duchenne reports having caused amaurosis by over-stimulation of the retina with a strong current. It is probable that the danger of injuring the retina is less than is supposed, since galvanic currents are used with great freedom about the face. The author has known of no instance in which injury was done to the retina.

When the galvanic current is applied about the face, a metallic taste is experienced. This is also caused in greatest intensity by the cathodal closing, and is due to stimulation of the gustatory nerve. When the Schneiderian membrane is stimulated, a peculiar odor is developed, but this reaction cannot be easily obtained, and currents of considerable intensity are necessary. We owe to Brenner, of St. Petersburg, also, the demonstration of the acoustic reactions obtained by galvanization of the auditory nerve. Brenner employed the rheostat or resistance coils now known under his name, for the purpose of exact measurement of the strength of the currents. When the auditory nerve is stimulated by the galvanic current, various subjective noises are caused, as whistling, ringing, roaring, rumbling, humming, etc., each of which is expressed by a symbol. To these observations of Brenner it has been objected that they are reflex through the fifth nerve, but Erb and other electrologists have fully confirmed them.

To apply galvanism to the ear, the external auditory canal is filled with tepid water acidulated slightly or containing a little salt. One electrode of suitable shape is introduced into the water and the other is applied to the neck, or to the mastoid process of the other side. A better aural electrode consists of a hard-rubber speculum with a small metal electrode in its centre, projecting a little beyond the extremity of the rubber. To use this, a little water is introduced into the canal, and the instrument is then passed as far as it can be without pain.

PART III.

ELECTRO-DIAGNOSIS.

CHAPTER I.

ELECTRO-CONTRACTILITY.

In practising the methods of electro-diagnosis, certain preliminaries must be adjusted. In the first place, both galvanic and faradic currents are necessary. In many cases, the result is determined by a comparison of the effects of the two currents. The position of the patient, or of the parts to be examined, must be carefully attended to. When the extremities are to be compared, the two sides must occupy symmetrical positions, and the muscles should be in an equal state of tension. If the object is to ascertain the condition of muscles, the conduction of the current through the skin should be facilitated by thoroughly moistening the skin and the electrodes. The size of the electrode becomes important when single muscles are to be examined. The small olive-shaped metal electrodes of Duchenne are admirably suited to pick out small muscles. They should be covered with soft leather, and be well moistened. The electro-contractility of the healthy muscle should be first determined, if our object is to ascertain the degree of departure of diseased muscle from the healthy standard. The muscles of both sides being affected, the comparison must be made with some other of equal capacity and vigor.

The pole used to excite is placed over the nerve or muscle to be acted on; the other on some indifferent point. If the current is weak, the conductivity of the electrode cover, or of the sponge, is increased by moistening with solution of salt; but if strong, it suffices to moisten it with water. In breaking the circuit, it is convenient to have an interrupting button in the handle, or the electrode may be simply put on and off as making and breaking are required. When cathodal, or anodal, opening or closing contraction is required to be produced, the mode of proceeding is as follows: the exciting pole is placed over the nerve or muscle to be excited; the other at any point, and the circuit is made or broken by the interrupter in the handle of the electrode, or by that on the pole-board, or by simply taking off and putting on the electrode itself. When it is desired to make comparative observations, the corresponding nerve or muscle is acted on in the same way, the part or member being in the same position, the skin wetted to the same extent, the electrodes of the same size and quality, and the current strength the same.

It is best to begin the diagnostic study by using the faradic current. Here the arrangement for slow interruptions will be found extremely useful, especially if a very strong current is necessary to cause muscular contractions. Ascertain the smallest strength of current necessary to induce contraction of the healthy muscle, and then compare it with the strength required to cause contraction of the diseased muscle. When the galvanic current is used, both the positive (anodal) and the negative (cathodal) opening and closing contractions are compared on the diseased and sound side.

There should be several observations made, at different times, to arrive at a correct conclusion, and during a

course of treatment, examinations are necessary, from time to time, to ascertain the progress made. Great care is required to limit the electric stimulation to the nerves and muscles under examination, and not to confound the effect of derived currents with the exciting current proper.

If a muscle or a group of muscles is paralyzed, it is the object of electro-diagnosis to determine the source and character of the causes. The cause may consist in a change in the condition or structure of the muscle itself, in the nerve supplying the muscle, in the spinal cord, in the basal ganglia of the brain, or in the motor centres of the hemispheres. What is the behavior of the affected muscles toward the electric current, under these various conditions?

ELECTRO-CONTRACTILITY. *Nature of the reactions to electric stimulation when the muscles are themselves diseased.*—When a muscle is exposed to a current of cold air under certain circumstances, it passes into a condition when it is no longer obedient to the will, and is relaxed and lifeless, or rigid and immovable as regards its power of contraction. This condition of the muscles is often exemplified by the deltoid, or the lumbar muscles, or the neck muscles (torticollis), when so exposed. Again, a muscle or group of muscles, overstrained at work, or crushed or bruised, may lose all power of contraction under the stimulus of the will, and may undergo atrophic changes. The most perfect example of a disabled muscle from intrinsic causes, is that of progressive muscular atrophy, if we adopt the theory of Friedreich, who maintains that the morbid process begins in the muscles, and extends thence to the nerves.

In the healthy condition of the muscle, it can be excited to contraction by a faradic current (faradic ex-

citability), and, also, by a galvanic current (galvanic excitability). The muscular contraction is the same, whether the motor nerve supplying the muscle is acted on, or the muscle itself is stimulated. If the former, it is called *indirect*, if the latter, *direct excitation*. When the muscles are entirely normal, the minimum strength of current sufficient to excite them will induce the same amount of contraction when applied to the motor nerves innervating them. If the same strength of current be applied to the symmetrical muscles or motor nerves on the other side, precisely the same amount of contraction will follow. In the diseased state of the muscles we find more or less departure from these normal reactions. It is important to note that great differences exist in the reactions to the electrical current of paralyzed parts. In some cases the *paralysis may be complete, and yet the nerves and muscles react in a perfectly normal manner.* We observe this normal electro-contractility in hemiplegia, whether due to cerebral hemorrhage, to embolism, or to tumors of the brain; also in some cases of myelitis, and in the slightest examples of some of the peripheral paralyses.

In other examples of paralysis, there are *quantitative changes*, merely, in the muscular contractions: simple increase of electric excitability; simple diminution of the same. As regards increase of excitability, it exists to both faradic and galvanic currents. In the former, the muscles react to a less strength of current, or contract more energetically to the same current-strength; in the latter, the normal formulæ are preserved, but the reactions are more decided—that is, a cathodal closing contraction (KaSZ) ensues with a very weak current, or an ordinary cathodal closing contraction becomes a tetanus (KaSTe) on application of the same current; the anodal

opening contraction (AnOZ) coming on early, and the cathodal opening contraction (KaOZ) readily occurring; and in rare cases an anodal tetanus contraction (AnOTe). These, it should be remembered, are normal in respect to the mode of reaction, but are merely exaggerated, or occur to a less strength of current than do the corresponding muscles on opposite side, or more energetically to the same strength. It follows that, to ascertain these quantitative changes, comparison of sound with paralyzed parts must be, and, indeed, can only be, certainly arrived at by such alternate and comparative examination. Increase of electric excitability is not common, and is seen most frequently in hemiplegia, with recent lesions; is rare in some spinal paralyses, and still more infrequent and brief in duration in recent paralysis of nerve and muscle of traumatic origin.

Much more frequently do we encounter diminution of electric excitability. As regards the faradic excitability, we find the strength of current necessary to produce a contraction lessen, until at last there may be no reaction to any degree of faradic excitation. As regards the galvanic excitability, we find the cathodal closing tetanus (KaSTe) first ceases, then anodal closing contraction (AnSZ) and anodal opening contraction (AnOZ) cease, and, at last, cathodal closing contraction (KaSZ) can be excited only by the strongest current. There may come a period when no form of galvanic excitation will produce the least reaction.

As the quantitative decline in the electrical reactions signifies a course of atrophy terminating in the complete disappearance of the muscular elements, such reactions, as might be expected, accompany the change taking place in progressive muscular atrophy and in certain spinal paralyses with wasting of the muscles.

There is still another group of cases of paralysis, in which there occurs both a qualitative and quantitative decline in the electrical excitability.

Immediately after a muscle — in consequence of a blow, for example—loses its power of voluntary contraction, it may still respond to electrical stimulation for a brief period; but if the blow is sufficient to set up retrograde changes in the muscle, there will come a time when it will not act to any kind of stimuli. When the muscle is undergoing atrophy, fibroid or fatty degeneration, or a chemical change which destroys its contractile elements, there will occur a condition in which it ceases to act normally to electric stimulation. At first, it ceases to respond to the faradic current; then follows a period when it will still act to a slowly interrupted galvanic current, and finally it cannot react to any form of stimulation, nor to galvanic or faradic currents, never so powerful. These peculiarities in the reaction of a diseased muscle have been called by Erb, "reaction of degeneration," and, as this is a fitting expression, it is likely to become current. At first no adequate explanation of these peculiarities of degenerating muscular tissue could be made. It is now understood, however, that, as the changes proceed in the muscle, the contractile element is so altered that it cannot respond to the faradic current, because instantaneous, whereas the galvanic still causes movements, because it passes in one direction and is slowly interrupted. There is, finally, such a complete destruction of the contractile element that no contraction can take place to either form of current.

Nature of the reactions to electrical stimulation when the motor nerves, supplying the muscles, are diseased.— It is very important to distinguish between the excita-

bility of nerve and muscle. This fact will come out distinctly when we study the effects of spinal lesions. Now we are concerned with simple phenomena due to injury or disease of the nerve, and the effect of such changes on the contractility of muscles. By paralyzing the end organs of the nerves with curare, Bernard demonstrated the existence of contractility as an endowment of muscular tissue. It has just been stated that the same amount of electrical energy applied to the motor nerve will cause the same degree of contraction as when applied directly to the muscle. The state of the nerve, then, has to do with a normal condition of the motor apparatus. When inflammation ensues in a motor nerve, there is a period when the irritability of the muscle is heightened, and a less degree of galvanic or faradic irritation will cause contractions than is necessary in health. If the nerve is softened and destroyed by the inflammation, the galvanic and faradic excitations have less and less effect, and finally the influence is extinguished, and no contraction can be induced. If a motor nerve is crushed or clearly divided with the knife, there is a brief period during which the electric excitability of the muscle to both currents is retained; but the muscle as well as the nerve undergoes degeneration (atrophy, fatty degeneration), and declines proportionally in the power to react to stimuli. A very slight increase of electric excitability is occasionally at first noted in the nerve, but usually a quantitative decline takes place from the second or third day. This decline of electric excitability, it should be noted, is with both faradic and galvanic currents. If the injury is complete and irreparable, this quantitative decline continues, and by the twelfth day, sometimes earlier, the electric excitability has entirely disappeared. The change begins in

the portion of nerve nearest the injury, and extends thence toward the periphery. When the injury does not destroy the nerve entirely, and is remediable, the diminution in electric excitability is not entire, and slow restoration occurs.

If a nerve injured in any of the modes above mentioned, so that it no longer transmits volitional impulses, and electrical stimulation produces no muscular contractions, should be restored by union of the divided extremities, or by recovery from the inflammation, some remarkable phenomena are observed. The first point to note under these circumstances is the fact that the muscles react to voluntary impulses before they do to galvanic or faradic stimulation. In other words, voluntary efforts can be made when the strongest galvanic or faradic current would not excite a tremor. Under these circumstances we may suppose, as Erb shows, that the nerve has regained its *power to conduct* but not its power to react to electrical excitation. He supposes in these cases that regeneration is not complete, and that the medullary sheath is yet wanting in great part or entirely.

Nature of the reactions to electrical stimulation when the spinal cord is the seat of the disease.—Very great differences are to be noted in the effects on the periphery of the position of the disease in the spinal cord. The group of "myopathies of spinal origin" is composed of those affections in which the motor columns—the anterior cornua—and the spinal motor nerves, and the associated muscles, are alike occupied by an atrophic degeneration. Progressive muscular atrophy, glosso-labio-laryngeal paralysis, and infantile paralysis, are examples. In these diseases an atrophic degeneration begins in the multipolar ganglion cells of the anterior cornua, the motor nerve roots connected with them. de-

generate, and rapid wasting and paralysis ensue in the muscles innervated by them. It must be borne in mind, as above stated, that there are differences as between nerve and muscle, and hence they must be studied separately.

In a few days after the paralysis is manifest—in two or three days, usually—a regular and steady decline in the electric excitability of the nerve takes place. This is a quantitative and not a qualitative change. It is found that not only are stronger currents required to produce contraction of the muscles, but that for a current of a definite strength the contraction produced is feebler than in health. This decline in the electric excitability continues, and by the end of the second week certainly, and sometimes by the end of the first week, the electric excitability is entirely lost, and then no excitation—galvanic or faradic—will cause the least trace of a contraction.

The first change that ensues is in the cathodal closing, which disappears, and cannot be induced by any ordinary strength of current; then the anodal closing contraction, and afterward the anodal opening contraction, cease, and finally cathodal closing contractions can be obtained only with the strongest current.

The reactions of degeneration as they occur in the muscular tissue must now be studied. They are very distinctive and have high diagnostic importance. Under the conditions of disease in the cord, now assumed to exist, namely, of that part of the cord from which the paralyzed muscles receive their innervation, quantitative changes occur in the *faradic* excitability of these muscles. The muscles, like the nerves, rapidly lose their excitability, but to the *faradic current* only. In about a week after the symptoms of paralysis manifest themselves, the

muscles begin to decline in their electric excitability, and at the expiration of two weeks it is totally extinguished, so that no strength of current will cause the least reaction. This loss of faradic excitability is permanent in the incurable cases, but when regeneration of the nervous tissues can be accomplished there will occur a restoration of the excitability, but it is always feebler afterwards, how complete, soever, the restoration may be.

The reaction to the *galvanic* current is very different. During the first week of the existence of the paralysis, the galvanic excitability declines with the faradic. A very remarkable change occurs in the second and succeeding weeks; the galvanic excitability then begins to increase, and this augmentation goes on for several weeks, and is coincident with qualitative changes in the order and manner of contraction. So great is the increase in the galvanic excitability, that a strength of current insufficient to move the muscles in the healthy state will now cause lively contractions. Qualitative changes are also to be noted. Whilst the normal contractions are nearly instantaneous, those induced by the galvanic current under these circumstances are slow and long maintained, the muscular tonus persisting during the whole time the current is passing. Whilst the galvanic excitability is increasing, there also ensues a progressive qualitative change in the law of muscular contraction. This change consists in a gradual and considerable increase of the anodal closing contraction, so that it soon equals, may even surpass, the cathodal closing contraction. The cathodal opening contraction declines in the same ratio, so that there occurs a complete revolution in the normal formula (Erb). In the further progress of these cases, as the muscular tissue undergoes atrophic degeneration, there ensues a progressive

quantitative decline in the contractions, whilst the qualitative changes above mentioned persist to the last; a very feeble anodal closing contraction being the last evidence of vitality in the muscle. When all the proper muscular elements disappear, no contractions can take place under any circumstances. When the morbid process has ceased, and recovery sets in, there occurs a gradual change in the direction of the normal reactions. The galvanic excitability diminishes, and the faradic excitability returns again, but the excitability remains below normal. This lowered state of the excitability is quite independent of the restoration of the motor nerve to its functions. It may occur that the abnormal excitability to the galvanic current of the muscles themselves may be present with a normal state of the galvanic and faradic excitability of the nerves.

The difference in the reaction of the muscles undergoing degeneration to the galvanic and faradic currents has already been explained, but it may be well to repeat that it is due merely to the fact that the muscle is in such a state that it cannot respond to an instantaneous current, but can react to currents of long duration.

Nature of the reactions to electrical stimulation, when the disease is above the paralyzed parts, or within the cranium.—When that part of the cord is healthy from which the peripheral nerves are given off, and if the nerves and muscles are free from disease, the electrical reactions as well as the reflexes will be perfectly normal. Suppose, for example, a transverse myelitis exists above the dorso-lumbar enlargement of the cord, leaving the latter healthy, all of the muscles and nerves of the lower extremity deriving their innervation from this point, there will be no quantitative or qualitative changes in the electrical reactions, except it may be a somewhat

more ready response to both forms of excitation. When the lesion is in the basal ganglia, or in the hemispheres above, no change occurs in the reactions of the paralyzed parts, unless, in the further progress of the case, alterations of a degenerative kind occur in the cord, peripheral nerves, or muscles. For example—in hemiplegia, from a clot in the corpus striatum, there is no change in the electrical reactions, except that, in some cases, the muscles respond more readily than the normal muscles do to both forms of currents; in other cases, the reactions are simply normal; in still others, there is a quantitative decline due merely to the degenerative changes in nerve and muscle.

Conclusions.—The condition of paralyzed muscles, when affected by causes within themselves, may be ascertained by the application of galvanism and faradism. Both currents are necessary, and the reactions obtained are indispensable to diagnosis of the condition of paralyzed muscles. The reactions of degeneration afford precise indications of the state of the muscles in certain forms of paralysis.

The motor nerves also react in a definite way to electrical stimulation, and they must be examined separately from the muscles to arrive at exact knowledge of their condition.

The reactions of degeneration afford us very important diagnostic indications as to the seat of spinal lesions, and separate broadly the so-called "spinal" from the "cerebral" paralysis.

CHAPTER II.

ELECTRO-SENSIBILITY.

Electrical Diagnosis of Eye and Ear Sensibility.—Brenner has contributed most of the existing knowledge on the subject of the electrical reactions of the eye and ear. Although his results have been confirmed by those competent to form a correct judgment, the subject must yet be regarded as *sub judice.* Certainly, the physiological reactions cannot yet be applied with success to the interpretation of diseased states of these organs. The reactions of the auditory nerve have been interpreted with better results than have as yet been obtained from the optic.

Electrical Diagnosis of Gustatory Sensibility.—Reactions can be readily obtained from the nerve or nerves of taste perception. For this purpose, a double electrode, insulated to the extremity almost, and leaving merely a point of the metal exposed, is most appropriate when the object is to excite the taste sensation and to define its limits. With the utmost care, notwithstanding the points of the electrodes are closely approximated, diffusion of the current must take place to a greater or less extent, and hence the results are of little value. When the gustatory nerve is excited by the polar method, the cathode, which has the more stimulating action, is applied to the nerve distribution, whilst the anode is put on some indifferent point. An electrode similar to the olive-shaped button of Duchenne, but smaller, is used for the cathode, whilst a moistened

sponge is attached to the anode. The former is applied along the distribution of the gustatory branches, and the reactions on opening and closing the circuit obtained. Various modifications of taste, in the normal condition, are thus developed, whilst in diseased states they are changed to different formulæ. It is not yet possible, however, to express these reactions in definite formulæ —hence the diagnosis of taste perception is limited to the presence or absence of reactions on electrical stimulation.

Electrical Diagnosis of Cutaneous Sensibility.—When electrical currents are applied to the skin, definite sensations, of a very painful kind, are produced; but faradic currents are more severe than galvanic. The objects in view in the investigation of the state of the skin are to ascertain the position, extent, and degree of the impaired sensations. As it is desirable not to confuse the observations by muscular contractions, the current should be confined to the skin itself. This is accomplished by drying the skin thoroughly, and then dusting the whole surface to be examined, with some drying powder, for the conducting power of the skin depends on the amount of moisture it contains. The metallic brush—a bundle of fine wires—and button-shaped electrodes are best suited to test the sensibility of the skin. The sensation produced by the faradic is that of a burning pain with tingling; by the galvanic, that of warmth, with prickling and tingling of the skin. The persistent use of strong currents destroys the power of the afferent nerves to communicate impressions to the brain.

Prepared in the mode indicated, the skin is gone over carefully, and the state of the sensation to the galvanic and faradic current noted. The faradic current is chiefly used for this purpose, because of the diffusion of the

galvanic, and the difficulty of confining it to the points of disease. In certain cerebral and spinal diseases, the sensibility to faradic stimulation of the skin is much impaired, and large tracts are entirely anæsthetic and analgesic. The boundaries of such anæsthetic regions can be neatly and accurately made out by the electrodes. In hysterical anæsthesia and hemianæsthesia, the sensibility of the skin to electric excitation is entirely wanting. Again, by means of electricity (galvanism) we determine the degree of electro-sensibility of the muscles. To arrive at a knowledge of the muscular sensibility, the galvanic current is preferably used; the electrodes are well moistened. The least strength of current that will cause muscular contractions only should be employed, since the pain caused by the action of the current on the skin ought not to interfere with the pain due merely to muscular contraction. When a muscle contracts firmly, a recognizable sensation referable to the contraction is felt. In certain conditions of disease, this sensation is wanting entirely. Duchenne formulates the electric diagnosis of hysterical paralysis as follows: "the electro-contractility of muscle is normal, but the electro-sensibility is diminished or abolished." Although there are many exceptions to this dictum of Duchenne, it is nevertheless true that this formula is of great service in diagnosticating hysterical paralyses. In cerebral paralyses—in hemiplegia—soon after the injury has been inflicted, the electro-sensibility of the muscles is lessened or abolished, whilst the normal contractility remains. In occasional cases of lead paralysis, the electro-sensibility of muscle has persisted, whilst electro-contractility has declined.

The state of sensibility of the skin may be utilized for determining the degree of narcotism, in cases of pro-

found insensibility. Strong faradic excitation of the skin will quicken, and at the same time deepen, the respiratory movements and the action of the heart, if the narcotism is not too deep. It follows, of course, that conclusions may be drawn as to the probable result from the greater or less influence which the cutaneous excitation has on the respiration and circulation.

The reactions of the central nervous apparatus may be utilized to determine its real state. In some cases of great torpor of the brain, and of the cervical sympathetic ganglia, currents of considerable strength are necessary to cause vertigo, flashes of light, and a metallic taste. In other cases, a feeble current from a single cup, for example, will cause very decided, even alarming, effects. This extreme degree of susceptibility is associated with a very mobile and impressionable nervous system. This extreme susceptibility to galvanic excitation is also acquired. Recent acute troubles, congestion and inflammation of the intracranial organs, have the effect to exalt the susceptibility. That the existence of this extreme susceptibility is a contra-indication to the use of galvanism about the head and face, is highly probable. In coming to conclusions on this point, it should not be forgotten that the appreciation of sensations of all kinds varies much in different individuals. The observation of internal sensations is a habit with many persons, who become proportionally acute in their perception of them.

Electricity is also employed in the diagnosis of feigned affections. These are assumed paralytic affections, due to some railroad or other injury. Often important medico-legal questions arise, and large sums are in question. More frequently than from any other cause, are local paralyses referred to the shock of a railroad accident, or to direct injury received. The resulting

paralysis is of the variety known as spinal. When the local injury is alleged to have affected the plexus of nerves, as the brachial, an assumed paralysis results. When the injury to the nerves is genuine, there will occur the reactions of degeneration, and the muscles will not respond to a faradic current, as has been set forth repeatedly. When the paralysis is feigned, the patient may resist as he will, he cannot prevent muscular contraction according to the normal formula; when, of course, the attempted fraud will be exposed. Again, it is alleged that the spine was injured, and that paralysis of the inferior extremities (paraplegia) has resulted. The rules already laid down must be applied here. If that part of the spine which innervates the inferior extremities, bladder and rectum, is diseased, the reactions of degeneration will take place; but if the injury is entirely above the dorso-lumbar enlargement, very different results will be obtained—the muscles will respond readily to either current.

If a tramp seek admission to the comforts of a hospital on the pretence of having a paralyzed arm or leg, he may be surprised by a faradic current, causing vigorous contractions of the muscles.

Finally, the electric current may be used to diagnosticate the existence of death. In a short time after death, *rigor mortis* sets in, the muscles lose their susceptibility, and cannot be induced to contract by any strength of current. Obviously, this means of diagnosis has but little importance.

PART IV.

ELECTRO-THERAPEUTICS.

CHAPTER I.

MAGNETO-THERAPY—THE THERAPEUTICAL APPLICATIONS OF THE MAGNET.

HISTORY.—So much suspicion has attached to the medical applications of the magnet, that the medical profession have rather avoided the subject. By some, the supposed and apparently actual effects were referred to the influence of the imagination, and by others were considered an arrant imposture. Since the era of Perkins' metallic tractors, all applications of this kind to the surface of the body have fallen under the same odium as finally attached to that redoubtable instrument. Since the era of "metallo-therapy" has come upon us, Perkins' tractors must receive more consideration. It was a remarkable delirium, that which seized on the believers in tractors, but the achievements of metallo-therapy have surpassed it. Indeed, Dr. Perkins was a man in advance of his age and a prophet, if the pretensions of metallo-therapy are maintained. Although his instrument was not a magnet, it was a combination of metals, supposed to exert an electrical influence.[1]

The earliest physiological studies of the effects of the

[1] The Efficacy of Perkins' Patent Metallic Tractors in Topical Diseases, etc. By Benjamin Douglas Perkins, A.M. (son of Dr. Perkins, the discoverer). London, 1800.

magnet on man were those of Baron Reichenbach;[1] but as he was bent on establishing his theory of an *odylic* force, and made no attempt to eliminate the various sources of fallacy, his observations are of little value. The subject, indeed, was quite a novel one when it was taken up for investigation by Dr. John Vansant, who studied the influence of magnets, not only on animal, but, also, on vegetable life, recording his observations in a paper entitled, "On the Physiological Action of Magnetism."[2] Having the advantage of a personal acquaintance with Dr. Vansant, I can the more readily accept his observations and experiments. After the publication of Dr. Vansant's paper, Dr. Hammond[3] essayed the application of magnets, and has recorded his experience. Since the rise of metallo-therapy, magnets have been frequently used to develop the peculiar phenomena of cutaneous sensibility; but certain metals are also useful, as was long since learned by Perkins, and as has been recently asserted by Dr. Burq.

Physiological Effects of Magnet Applications.—It is very difficult to separate any disturbances due to the imagination from those produced by the magnet. All of the phenomena are so entirely subjective that the effects can only be obtained from the patient, and an objective study is not possible. We know that a current circulates in a magnet. If a powerful horseshoe magnet is brought near to the skin, opposite electricities are attracted to the poles, and currents are induced. About the point of application, therefore, the skin will be acted on directly by the magnetic current, and by

[1] Quoted by Dr. Hammond, Neurological Contributions, No. 3, p. 45.

[2] The Journal of Psychological Medicine, New York, April, 1870, p. 264.

[3] The Therapeutical Use of the Magnet. Neurological Contributions, No. 3, p. 44.

an induced current. The production of physiological effects, which can be recognized, is, therefore, merely a question of the magnetic strength.

Dr. Vansant found that the south pole of a bar magnet applied to an accidental blister on his finger "gave rise to a momentary, sharp sensation," but when the north pole was applied there was "no sensation at the moment of contact, and after its removal the original pain remarkably subsided." Interested by this accidental observation, he then tried the effect of the magnet poles on the most sensitive normal surface—the conjunctiva. The previous observation was confirmed: the south pole excited pain on contact, which was independent of the sense of touch, but no corresponding irritation from the north pole was experienced. To eliminate the influence of the imagination, Dr. Vansant extended his investigations to plants and to the lower animals. He found that the application of a magnet near, or barely in contact, as well as gently touching the plants, "exerted an influence on their vitality." "The shrivelling petals, the changing color of the flower and leaves, the sudden emission of perfume, and the early decline," were the evidences of the action. On small animals—earthworms and spiders—the magnet acted powerfully, causing death on alternate application of the poles. On larger animals, the effects were excitant or soporose, according to the mode of application. The polar effects were very remarkable as developed in man. As a result of a large number of observations, Dr. Vansant ascertained that there were regions reacting in certain well-defined manner to the poles. The method which he pursued to determine the actual polar condition of any part of the human body, consisted in ascertaining "by numerous trials on the same person,

and on different ones, that a given pole of a magnet placed in contact a short time with a given part or organ, would give rise to a set of symptoms of a definite character, varying apparently only in intensity." He "then found some other part, which, when tested by the same pole in the same way, produced a similar set of general symptoms." It was in this way ascertained that the two parts were in the same polar state. By the application of opposite electricities, he found that different reactions followed. "When a positive magnetic pole is applied to a positive part of the body, a tonic effect, or an exalted vital action, ensues." This is explained by Dr. Vansant by assuming that the body is diamagnetic. By applying north and south polarity to different parts, very extensive subjective impressions are experienced: they are of two classes—of heightened organic activity and of a lowered functional condition.

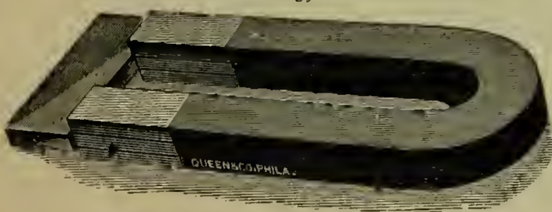
That impressions of a very decided kind are produced by the application of strong magnets is evident in the experience of Drs. Proust and Ballet, who continued a course of investigation begun by Charcot at Salpetriére.[1] They ascertained that magnets could not be applied with impunity, and that patients complained of disagreeable sensations not belonging to any malady for which the magnets were used. Hence it was difficult to induce them to continue a course of experiment for any length of time. If the magnet applications were prolonged and strong, pains were felt in the epigastrium and in the front wall of the thorax, making respiration painful. The pains were accompanied by disorders of digestion, and a condition of boulimia was brought on. The uniformity with which such results followed, and the strong repugnance

[1] Metallo-therapy. By Dr. L. H. Petit, Bull. Gén. de Thérap., March, April, May, June, 1880.

manifested by patients to a continuance of the applications, indicate that the effects were genuine. This conclusion seems all the more justifiable because the complaints made had no reference to the course of experiment.

Therapeutical Applications of Magnets.—The form of magnet employed by Dr. Vansant is "a round bar of steel, eight inches long by one-third of an inch in diameter, with a wooden handle affixed to the middle." Dr. Hammond prefers the horseshoe magnet, and advises that several of the same size be kept, so that a large and more powerful one can be made by clamping the smaller ones together. In the annexed diagram (Fig. 59) is exhibited the form of the instrument now em

FIG. 59.



Permanent compound medical magnet.

ployed by the metallo-therapists, and used by the author and by neurologists generally.

Some very surprising therapeutical results have been obtained by applications of the metals, but the system of Burq is yet in too uncertain a state to be adopted finally. Nothwithstanding the comparative meagreness of the information, it is certain that magnetic applications are based on sounder principles. That they accomplish remarkable results sometimes is certain. Vansant gives but few cases of disease so treated, his object being to develop the physiological actions. He

found the south pole of the magnet to give marked relief in *neuralgia.* As he used the bar magnet, he could obtain only polar effects, and the conclusion to which he arrived was that the north pole excited irritation and the south pole allayed it, and was, therefore, to be used in cases of neuralgia. Hammond insists on the necessity for the application of both poles in many cases, and therefore uses the horseshoe magnet. A much larger experience is needed as to both modes of application, especially as to the polar. In Charcot's *Archives*, MM. Debouve et Boudet report two remarkable cases of *hemiplegia with hemianæsthesia*, in which applications of the horseshoe magnet for some hours brought about at once most remarkable improvement. Hammond has used magnets in nine cases of *chorea;* in two "complete cures being produced in a few minutes," but in seven "no result followed." In the first successful case, "there were jactitations of all the limbs, and of the muscles of the trunk and face," and "she had lost the power of speech." Two horseshoe magnets, each capable of supporting four pounds, were so adjusted that one rested over the sternum, and the other over the cervico-dorsal spine—the poles pointing downwards. In two hours all symptoms ceased, including the return of speech, and there had been no reappearance of the malady in three months afterward. In the other successful case, the jactitations were unilateral, and ceased in eleven minutes after the magnets were applied. In two cases of *hemiplegia*, with *hemianæsthesia*, Hammond had very surprising results from the application of horseshoe magnets, the sensibility returning immediately, and in one the hemiplegia recovered from in a few hours.

In the course of the researches of MM. Proust and Ballet, alluded to above, they experimented with mag-

nets on eleven subjects. Eight of these were women affected with various manifestations of hysteria—hystero-epilepsy, hemianæsthesia, etc.—and three were men who suffered from sensory hemianæsthesia, due, one to lead-poisoning, one to the action of sulphide of carbon, and one to organic cerebral lesion, probably cerebral tumor. All of the sensory hemianæsthesiæ disappear temporarily under the action of magnets. The number, the strength, and the time of the applications necessary to secure this result, vary much in different subjects. In some of the cases, the application of a single magnet for fifteen to twenty minutes suffices to effect the return of sensibility; in others a number of magnets applied for many hours may be required. The action of magnets is more permanent than is that of metals, and the former act primarily on the nervous centres, whilst the latter act more on the periphery, restoring sensibility for a small space around them.[1]

Vigouroux[2] narrates a number of examples establishing the efficiency of magnets in removing hemianæsthesia, and he also reports a case of contractures, resisting all other means, thus cured. The same results have been obtained outside of France, and many of the instances are narrated by Petit.[3] Erlenmeyer, however, reports a case of hystero-epilepsy, in which remarkable results were had from statical electricity after the failure of magnets, metals, and galvanization.

A review of the subject must convince any unprejudiced observer that magnets possess distinct therapeutical properties. Owing to the nature of the subject, and the subjective character of the phenomena, it is

[1] L. H. Petit. Supra.

[2] Le Progrès Médical, 1878, Nos. 35, 36, 39; 1879, No. 8.

[3] Metallotherapie. Supra.

difficult to separate the effects of the magnet from the influence of the mental state. Enough is established to justify the use of the magnet in the cases in which it has had good effects. There is danger of the magnetic applications degenerating into charlatanry, and hence circumspection is necessary. Good results may be expected occasionally in *chorea*, more frequently in *neuralgia*, and still more certainly in various manifestations of *hysteria*, notably in those affecting sensibility.

CHAPTER II.

STATIC ELECTRICITY—ITS METHODS AND USES.

History.—After the first successful attempts to produce an electrical machine, up to the discovery of Franklin, there was more or less use made of the new force by all classes of society. After the time of Franklin, there was a return to the legitimate applications of electricity, but the practice very soon lapsed into the hands of ignorant charlatans, so-called specialists, and was entirely given up by the medical profession. The subsequent revival was due chiefly to the efforts of Dr. Golding-Bird, of England; but the interest in it was confined for the most part to the staff of Guy's Hospital. In an interesting paper by Dr. Addison,[1] of Guy's, we find the aspects of the electrical question, as they existed at that time, well stated:

"As a last resource, I determined on giving electricity a trial. I was, perhaps, in some measure induced to do so in consequence of having an opportunity of securing

[1] Guy's Hospital Reports, vol. v., October, 1837, pp. 493–507.

the assistance of Mr. Golding-Bird in its application. The effects produced by it at once gratified and surprised me, and led to further trials, the results and particulars of which will not, I trust, be deemed altogether unworthy of the attention of the profession. Of course, all claim to originality, or even novelty, is out of the question; electricity having been long enumerated among the ordinary remedies applicable to convulsive disorders generally. It is, nevertheless, much to be feared that many persons, like myself, have been led greatly to underrate its efficacy, either in consequence of its vague and indiscriminate recommendation, or from the inefficient and careless manner in which it has been applied." Dr. Addison's remarks apply, of course, to static electricity, as at that time galvanism had been used to a slight extent, and faradism was just discovered. The method of application employed by Dr. Addison consisted chiefly in shocks or charges transmitted through the part to be acted on. Dr. Golding-Bird and Dr. Addison often employed a charge stored up in the Leyden jar, which was sent through the pelvis or other parts of the body.

Dr. Addison reports in his paper six cases of chorea and one of hysterical paralysis, cured by electrization, sparks being drawn from the spine. Some of these cases were of remarkable severity, and resisted all the means of treatment which could be instituted, but yielded promptly and wholly to the electrical applications. Some years subsequently, Dr. Golding Bird[1] described the electrical room at Guy's Hospital, and reported cases of disease treated by electricity. In his comments on the cases of chorea (p. 97), he remarks as follows:

"It may now be asked in what light is electricity to be

[1] Guy's Hospital Reports, vol. xii., April, 1841, p. 81.

regarded in the treatment of chorea, and certain involuntary motions of the voluntary muscles analogous to those occurring in this disease? From the results of the cases treated at Guy's Hospital, no doubt can remain on the mind of any one that electricity really exerts a decided, not to say specific, influence on these affections; and although on its first application all the symptoms often become increased, from probably the timidity of the patient, and the novel character of the remedy, yet, where it has been persevered in, in thirty-five of the thirty-six reported cases, it has either completely cured or greatly relieved the patient; the case in which it failed, the twenty-ninth in the table, could scarcely be regarded as a fair one, as there was but little doubt that disease of the membranes of the spinal cord existed." In the treatment of these cases, Dr. Bird employed the method hereafter described as the electric bath, sparks being drawn from the spine, the *séances* lasting from ten to fifteen minutes. This method of electrization was also used by Bird in the treatment of paralytic affections. He alludes as follows to forty-four cases of paralysis:

"Of these it may be generally remarked that those in which the paralysis, whether of sensation or motion, or both, depended on exposure to cold or rheumatism, upon some functional affection, often of a local character, or upon the impression produced by effusion in some part of the cerebro-spinal centre which had become absorbed under the influence of previous treatment, the result of the application of electricity was most successful; whilst in those cases in which the paralysis depended upon some persistent structural lesion, whether produced by accident or otherwise, I never saw the slightest beneficial result." Amongst the cases are some remarkable cures of lead palsy—dropped wrists—of hemiplegia, para-

plegia, and of peripheral paralysis. Passing shocks through the pelvis, one knob on the sacrum and the other against the pubes, proved decidedly beneficial in cases of amenorrhœa. As Dr. Bird says: "Scarcely any cases have been submitted to electrical treatment in which its sanatory influence has been so strongly marked as in those in which the menstrual function was deficient. . . . The rule for insuring success in the great mass of cases of amenorrhœa is sufficiently simple: improve the general health by exercise and tonics; remove the accumulations often present in the bowels by appropriate purgatives; and then a few electric shocks, often a single one, will be sufficient to produce menstruation, and at once to restore the previously deficient function" (p. 114).

"A further report on the value of electricity as a remedial agent," appeared in 1851, from another member of Guy's Hospital staff—Dr. now Sir William W. Gull.[1] By this time faradism was being urged by Duchenne, and galvanism by Remak. Dr. Gull, in comparing the effects of these different modes of electrical energy, decides in favor of the superior efficacy of static electricity. "I have tried," he says, "such currents, both direct and inverse, in several cases of tic douloureux and other forms of neuralgia without benefit. . . . . Neither has it appeared to me that any practical advantages have resulted from employing shocks from the direct current in paralysis."

In 1873, Dr. Wilks,[2] another eminent member of Guy's Hospital staff, thus expresses himself on the subject of the change of practice in the substitution of galvanism and faradism for static electricity. "After the introduc-

[1] Guy's Hospital Reports for 1851.

[2] Ibidem for 1873.

tion of electro-magnetism or faradization, frictional electricity fell into disuse; but I feel confident that it was not successfully superseded by the new method." That which Dr. Wilks has to say in regard to the electrical treatment of chorea is probably true of some other disorders, in which galvanism and faradism are now used.

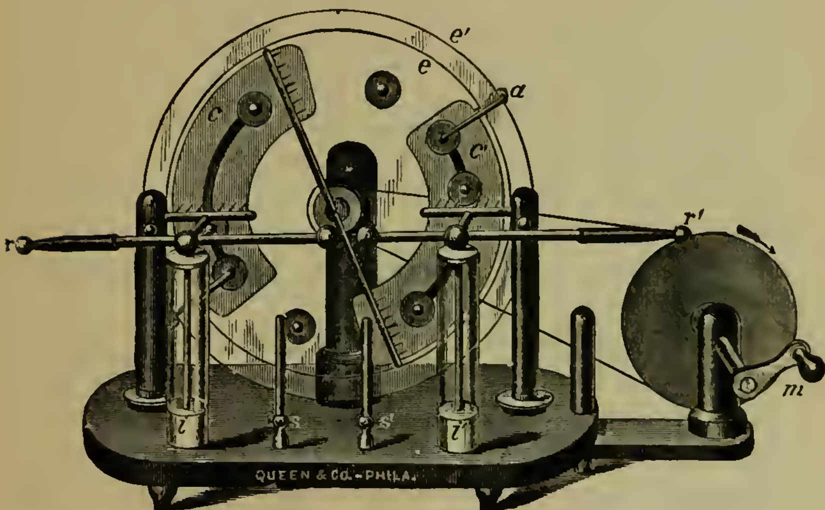
The modern revival in the use of statical electricity is more especially due to Charcot and his pupils, especially to Dr. Arthius,[1] and afterwards to Dr. Vigouroux, of Paris. The efforts of Guy's Hospital men extended but little influence beyond their own circle. In this country, Dr. W. J. Morton, of New York, the author, and Dr. Geo. M. Beard, were most active in introducing the new view of statical electricity into the literature and medical practice of this country.

The Appliances of Statical Electricity.—Static electricity may be applied by means of the plate, the cylinder, or the Holtz machine. The last mentioned, as it has been lately improved, is both highly efficient and certain in operation. The instrument used by the author was originally a Holtz machine, but on learning the advantages possessed by the Toepler modification, he had the changes made by Messrs. J. W. Queen & Co. This machine has now (July 1) been in continuous use since September, and has never failed to furnish the maximum effects of which it is capable. During this period, it has been standing on a table in my consultation room, without any cover of any kind. The diameter of the fixed plate is 16 inches, and of the revolving plate 14 inches, and it presents the appearance shown in Fig. 60. The Holtz machine has been variously modified by different

[1] L'Electricité Statique et L'Hystérie, etc., par le Dr. Arthius, Paris, 1881. Dr. Arthius controverts the claim of Dr. Vigouroux to be the pioneer in the use of static electricity in hysteria.

makers, and, as a rule, improved. In the Toepler-Holtz the windows have been omitted from the fixed plate. On the revolving plate are clamped at regular intervals brass knobs, against which some bunches of tinsel (*a*, *a'* Fig. 60) are arranged to brush. In my instrument the brush attached to *a* is composed of brass wire, stiff enough to scratch with some force. The original instru-

FIG. 60.



The Toepler-Holtz electrical machine.

ment was capricious, and was not, therefore, suited to purposes which demand, above all things, constancy and uniformity. The simplest cylinder or plate machine will, however, be sufficient for medical uses, provided it work well under all circumstances. Positive or negative electricity can be obtained—positive from the prime conductor, and negative from the rubber. The electricity may be communicated to the patient by conduction, or by disruptive discharge. The patient placed on an insulated stool, body in communication with the nob of the prime conductor, or the rubber cushion, becomes

charged with positive or negative accordingly. I am unable to discern any difference in physiological or therapeutical effects, in the actions of the two forms of franklinic electricity.

The Electric Bath.—Placed on the insulated stool, as mentioned above, the patient is more or less highly charged with electricity, which is silently received without pain, as it does not pass by disruption. The hair is deflected from the scalp, the surface becomes warm, the cutaneous circulation is active, the face flushed, the action of the heart is quickened, and the pulse is more rapid. A general sense of tingling in the skin is experienced, and an abundant perspiration breaks out over the body. If now the knuckle of the operator, or a brass knob, is presented to any part of the body, a spark passes with a stinging sensation, and a wheal is ultimately formed.

An insulated stool may be made by placing a strong board having the proper dimensions on four stout glass tumblers. An ordinary chair may be insulated by putting on the legs the rubber tips now constructed for preventing damage to the carpet or floor. A brass chain of the size used with electrical machines is a convenient means of connecting the patient with the machine.

The operator will find it very inconvenient to draw off sparks with his knuckles, and hence should use an insulated brass knob, having a suitable handle and a chain communicating with the floor. It is also convenient to have a loop, by means of which the chain is held away from the patient, for painful sparks pass on contact. If the machine has sufficient power, sparks can be drawn through the clothing, but much more pain is given than when drawn from the skin immediately.

Nerve and Muscle Effects of Statical Electricity.—About the same time, Dr. W. J. Morton, of New York, and the author, ascertained that effects in no respect distinguishable from those produced by faradic electricity could be procured from the Holtz machine. Dr. Morton begins by separating the outer coating of the condensers (*i*, *i*, Fig. 60), accomplished by removing the communicating bar underneath the platform. By attaching to the base of the condensers ordinary rheophores and electrodes, and placing the discharging rods (*r*, Fig. 60) in communication, the current is drawn off. I find the current can be easily tapped without displacing any part of the machine, as follows: I fasten one brass chain around the top of one condenser—the left-hand one facing the machine—and another brass chain around the base of the other condenser, and to each chain an ordinary electrode, preferably a carbon electrode covered with leather, is attached. The discharging rods are placed at a distance apart which is determined by the effect to be accomplished, which consists in the faintest tingling when the rods are nearly together, or the most powerful muscular contractions when they are some distance apart. The same kind of irritation of the sensory nerves is caused by this interrupted current as that caused by the faradic, but it is softer. When the discharging rods are slightly separated, a weak muscular contraction is induced at every interruption. If the plate is made to revolve with the maximum speed, no distinct muscular contraction—only a faint vibration—is observed. When the sparks pass slowly and some distance apart, strong muscular contractions are induced with each interruption. The most powerful contractions are caused without pain. In this respect static electricity possesses distinct advantages over faradic. Dr. Morton

employs an interrupting handle electrode in his mode of using this current to produce muscular effects. Such an interruption is necessary, since the discharging rods are kept in opposition; but, used as I have above described, no special electrodes are necessary. Indeed, just so much of the current is taken as may be required, and the physiological effects correspond to the doses administered.

Therapeutical Applications of Static Electricity.—Electrization by sparks has been applied with great success to the treatment of *neuralgia*. Sparks are drawn from the integument overlying the nerve. If the machine is powerful and the nerve superficial, sparks can be drawn through the clothing, but this practice is more painful than when the sparks are drawn directly from the skin. The varieties of neuralgia thus treated are *trifacial*, *cervico-occipital*, *intercostal*, *sciatic*, etc. I have found it successful in all of these four, and Morgan[1] sums up his experience by saying that this treatment gives more prompt relief in sciatica than any other agent.

In the treatment of *hysteria*, statical electricity has achieved its greatest triumphs. In the severest examples of *hystero-epilepsy* it has succeeded in the hands of Charcot and his pupils, especially Vigouroux. Dr. Arthius[2] has made it clear that he was the pioneer in this movement, and that afterwards the use of static electricity was taken up by Charcot. It is of little moment who initiated the practice, as compared with the important therapeutical results which have been obtained by the use of this agent in all hysterical affections. A single sitting may sometimes remove *aphonia*, a *paralysis*, a *contracture*, *hemianæsthesia*, even *hystero-epilepsy*, but as a rule the number of applications has a certain

[1] The Journal of Nervous and Mental Diseases, April, 1882.

[2] L'Électricité Statique et L'Hystérie, Paris, 1881.

ratio to the severity of the hysterical affections. The electric bath and electrization by sparks are the usual modes of application. Sparks should be drawn from the affected area or region. It is not only the French physicians who have found the best results from this treatment, but the conservative Germans also report facts strongly confirmatory of the French observations. Thus Erlenmeyer,[1] an eminent German neurologist, reports a case of hystero-epilepsy, in which, after the failure of magnets, metals, and galvanization, statical electricity succeeded perfectly.

In the treatment of the various forms of *paralysis*, when the muscles are in a condition to react to stimulation, and under the circumstances in which heretofore faradic applications have been made, static electricity will be found preferable. The mode of arranging the instrument for muscular effects has been explained. The advantages possessed by this treatment are the efficiency of the contractions, and the painlessness of the applications. Slow or rapid interruptions are readily obtained, and the strength of current required does not give rise to any pain in the skin.

In the various *neuroses* involving either the motor or sensory sphere, static electricity produces excellent results. In *chorea*, *torticollis* and *histrionic spasm* recent in origin, *muscular contractures*, etc., good effects are had from this remedy. In these affections the over-acting muscles are quieted by a weak current very rapidly interrupted, and the paretic muscles are strengthened by pursuing the opposite mode.

Static electricity, like faradism when applied generally, has distinct tonic effects, and in a higher degree than the latter. To procure the tonic and reconstituent

[1] Centralblatt für Nervenheilk., No. 1, 1879.

effects, the patient is placed in the electric bath, and sparks are drawn from the organs of vegetative life—from the hepatic, splenic, umbilical, iliac, and thoracic regions, from along the spine and over the extremities. I have seen some cases of phthisis remarkably improved by this practice. It is surely deserving of more attention than it has hitherto received.

CHAPTER III.

ELECTRO-THERAPEUTICS IN GENERAL—ELECTRICITY IN CEREBRAL AFFECTIONS.

The passage of galvanic currents through the brain has been clearly established. As the superior ganglion of the cervical sympathetic exerts an immediate control on the cerebral circulation, and as it can be acted on by galvanic excitation, it is obvious that we possess in galvanism an agent which can influence the intracranial circulation, and the nutrition of the intracranial organs.

Certain precautions are necessary in making galvanic applications to the brain. Before applying the electrodes the operator should test the strength of the current on himself. Strong currents are never proper about the neck, face, and head, under ordinary circumstances. When an extreme degree of susceptibility exists, the applications should be made very cautiously, beginning with a fraction of a cup by means of the rheostat, and gradually increasing the strength if necessary.

Cerebral Congestion.—Excellent results are obtained in cerebral congestion by galvanism and faradism. Frequently interrupted galvanic applications are best

adapted to this purpose. The positive electrode—anode—is placed in the fossa behind the angle of the jaw, and the cathode on the fifth, sixth, or seventh cervical vertebra, and interruptions (anodal) are practised every few seconds. As in the opening and closing the circuit, flashes of light and vertigo are experienced, caution must be exercised. Patients unacquainted with the sensations produced by galvanism are apt to disregard the lighter disturbances, and to demand something that can be strongly felt. They should, therefore, be instructed in the character of the effects to be produced. The interruptions should produce only the faintest possible flashes of light and the most transient giddiness. The applications ought not to exceed three minutes in duration including interruptions, and should be made daily. If some improvement is not perceptible after a few applications, no good will be accomplished by a repetition of them, but if good results are obtained they ought to be continued, with occasional intermissions, until recovery. Faradic applications may be made to the lower extremities as a derivative in cases of cerebral congestion. For five minutes the leg and thigh muscles should be made to contract and the skin excited. The effect of this treatment is to increase the amount of blood in the lower extremities, and to raise their temperature, and consequently to lessen the amount passing to the intracranial organs. There are persons, however, who possess such an irritability of constitution, that faradic excitation of the members will cause a general increase of circulation and elevation of temperature. In such subjects faradization of the lower limbs should not be practised for the relief of the disease under consideration.

Cerebral Anæmia.—It would seem paradoxical to assert that a remedy effective for cerebral hyperæmia should

also be useful in cerebral anæmia, but very different results follow variations in the mode of applying the currents. In cerebral anæmia, as in the opposite states, only the feeblest currents are proper. The electrodes are applied on the forehead and nape of the neck, and on the mastoid process of each side. The applications should be stabile, and for not more than a minute in each direction. Applied in this way, the intracranial circulation is promoted, and the nutrition of the brain improved. No very striking results can be expected from a few applications, and when benefit is experienced it is gradual. If, after ten days of daily applications, no good whatever is apparent, it will be useless to continue them. When cerebral anæmia is a part of a general anæmia and not local, and when the anæmia is due to a depressed state of the assimilative functions, much benefit is derived from general faradization and central galvanization—methods and conditions of which more will be said hereafter.

Partial cerebral anæmia is a more important state as regards electrical treatment. Certain districts of the cerebrum—notably, the region supplied by the left middle cerebral artery—may be suddenly deprived of blood by embolic obstruction of a vessel. Often there will be associated disease of the left heart, especially of the mitral valve, right hemiplegia, and aphasia. Under these circumstances embolic blocking of the left middle cerebral, or one of its branches, has taken place with the phenomena of apoplexy. Such an accident occurs in young persons. In the aged, however, local cerebral anæmia is produced at various points in the brain by endarteritis, roughening of the intima, and coagulation of the blood closing the vessel finally as the obstructions encroach on the lumen. Not alone does anæmia follow

in the area supplied by the obstructed vessel, but if the artery be a terminal artery,[1] collateral hyperæmia and œdema follow. Under these circumstances is galvanism proper as soon as the immediate effects of "the stroke" pass off? We hold that it is. Much of the damage done in these cases is due to the collateral hyperæmia and œdema, for if such anastomoses existed as would enable the circulation to be carried on, the symptoms of local anæmia would soon disappear. To restrain the hyperæmia and to promote absorption of the effusion, are the important objects to be accomplished by the use of galvanism. In similar hyperæmia and œdema of external parts, the good effects of the galvanic current in restoring tone to the distended vessels and in causing absorption of œdematous effusion are very conspicuous. Although it may be supposed that the quantity of electricity reaching the affected region is too small to be of any use, because the application of weak currents is held to be essential, yet it is certain that some good is done by them. Transverse and longitudinal currents should be transmitted through the cranium, beginning their application after the effects of the shock have subsided, produced by the sudden anæmia.

In the case of thrombosis of the cerebral vessels, we have to deal with very different conditions. Instead of sudden blocking of a considerable vessel of the brain, and the resulting anæmia, there occur, owing to changes in the walls of the vessels, gradual occlusion by clots of small vessels, arterioles, and capillaries. The interference with the nutrition of the brain, which this widespread disease of the vessels involves, leads to serious disorders of function. As regards the mental condition, there ensue melancholia, senile dementia, and other forms

[1] Cohnheim, Untersuchungen über die Embolische Processen.

of mental derangement; but that state especially for which electrical treatment is so serviceable is the gradual failure of mental power, with the headache, vertigo, and muscular feebleness associated with it under these circumstances. In another group of cases, owing to atheromatous changes in the vessel walls, miliary aneurisms form, and such interference with the nutrition of the brain is the result in many instances, that failure of memory, of the power of attention, and of the mental faculties in general, and an emotional state occur. There can be no question of the great value of a weak galvanic current, slowly interrupted, in such cases, but the applications should be kept up for some time.

Dr. Löwenfeld[1] has formulated the following conclusions regarding the action of galvanism on the brain: The positive pole at the forehead, and the negative at the neck, determine a contraction of the arteries of the *pia mater*. When the position of the poles is reversed —that is, the anode at the neck, and the cathode at the forehead—dilatation of the arteries ensues. When the galvanic current is made to pass through the brain transversely, dilatation of the vessels occurs on the side of the anode, and contraction on the side of the cathode. Erb and other authorities deny the accuracy of these observations.

The treatment of *psychical disorders* by electricity has been productive of some very striking results. The most important contributions to this subject have been made by Arndt,[2] Allbutt,[3] Williams,[4] and others. A high

[1] Experimentelle Beiträge zur Elektrother. des Gehirns. Centralbl. f. d. med. Wissensch., No. 8, 1881.

[2] Zeitschr. für Psychiatrie. Band 34, p. 92. Zur Electrotherapie der psychischen Krankheiten. Also, Band 28.

[3] West Riding Lunatic Asylum Reports, vol. ii. p. 203 *et seq.*

[4] London Medical Record, vol. i. p. 413.

grade of psychical hyperæsthesia is regarded by Arndt as a contraindication. This view coincides with the experience of Williams, who finds that the mania of bodily weakness is the particular field of usefulness of electricity. Arndt further points out that those cases are favorable to the action of this remedy in which the mental disturbance is due to vascular conditions. When stupor and insensibility are the objects of treatment, then faradism, he holds, is the proper agent. The mode of application which he advises consists in placing the anode over the central organs and the cathode at the periphery. Clifford Allbutt, of Leeds, has made some valuable, if not extended, observations, at the West Riding Lunatic Asylum, on the effects of electricity in various kinds of mental derangement. He concludes that galvanism does good in acute primary dementia—that "marked improvement took place" in these subjects. In "mania, atonic melancholia, and perhaps recent secondary dementia, distinct improvement was noted, but to a less degree than in primary dementia." "In chronic dementia, and in some cases of melancholia, no change was induced by the current, and it acted unfavorably in hypochondriacal melancholia, and perhaps brain wasting." Williams reports eleven cases in which electrical treatment was pursued, and in five of these the results were remarkably good. The kind of cases benefited were those mentioned above—cases of mental derangement due to depression and bodily weakness. The result of the experience with electrical treatment in the Vienna general hospital,[1] and by Letourneau,[2] is quite in accord with that just narrated. The improvement was most marked in the cases of slight psychic disturbance occur-

[1] Wiener med. Presse, Nos. 14, 17, and 19, 1874.
[2] Gazette des Hôpitaux, No. 119, 1878.

ring in anæmic subjects. The testimony from widely separated and independent sources seems conclusive of the value of galvanization in cases of mental disorder due to or accompanied by the evidences of bodily depression. It is probable that the curative influence of the electrical current is due mainly to the excitation of the intracranial circulation. It has been pointed out in the physiological section that galvanization of the vasomotor system stimulates the vermicular motion of the arterioles, and thus promotes the circulation through the parts acted on. Arndt suggests peripheral faradization as a means of stimulating the intracranial circulation. There can be no doubt, however, that galvanization is the proper kind of electrical stimulation. The mode of application in these mental disorders is as follows: Well-moistened electrodes are placed on the forehead and nape of the neck, and on the mastoids, so as to transmit transverse currents; the superior ganglion of the cervical sympathetic is included within the circuit by placing one pole (the anode) in the fossa behind the angle of the jaw, and the other pole on the neck, about the *vertebra prominens;* and central galvanization is practised by placing the negative pole on the epigastrium, and the positive, in turn, over the pneumogastrics, the cervical and dorsal spine, etc. For the fossa behind the angle of the jaw, electrodes *c* and *d* are suitable shapes, and *b* and *a* for the neck and epigastrium (Fig. 61).

Fig. 61.

Electrodes, arranged to screw on handles, which are not shown.

CHAPTER IV.

ELECTRICITY IN SPASM AND CRAMP.

In the medulla oblongata and the spinal cord are situated the centres concerned in spasm. In the medulla is placed by Nothnagel his "spasm centre," and above this organ is the inhibiting centre of reflex movements (Setschenow's). No fact in regard to galvanism is more conspicuous than its power to allay spasm. When a strong current is passed through a muscle, it remains perfectly quiescent and relaxed until the current is broken. The irritability of motor nerve and of muscle is allayed by galvanism. From the theoretical stand-point, it is the descending current which possesses this property, but in practice it is found that the direction of the current is of little importance. Galvanism diminishes irritability and faradism increases it, and they are applicable accordingly.

Galvanism has been used with variable but not striking results in the treatment of *epilepsy*, by Gumplowiez and Klotzberg,[1] Rockwell,[2] Arndt, Allbutt, and others. The experience with this treatment has developed certain facts: 1st. It is adapted to the cases of essential epilepsy, and is without influence over symptomatic epilepsy, or epileptiform seizures; 2d, it is admissible in the cases characterized by anæmia and depression of the vital forces, and is not useful in the conditions of plethora. The best results have been obtained by Rockwell, and

[1] Wiener Presse, op. cit.

[2] New York Medical Record, April 3, 1878.

by Althaus,[1] but it does not appear that curative effects have ever been observed. Rockwell employed the method known as "central galvanization." Severe cases of *chorea* sometimes yield very promptly to galvanization of the spine and of the sympathetic—an example of which is related by Leube.[2] This treatment has also been successful in the hands of Benedict, who, in addition to spinal and sympathetic galvanic applications, faradizes the voluntary muscles generally. Under this treatment of combined galvanism and faradism, cures are effected in a short time (Althaus). Static electricity was long ago successfully used in the treatment of chorea by Dr. Addison ; afterward by Golding-Bird and Gull, and more recently by Vigouroux, Hammond, and others. The electric bath (patient on an insulated stool), and electrization by sparks drawn from the spine and muscles, have lately been very successful. The magnet, as has been shown in the chapter on that subject, sometimes is surprisingly effective, but usually fails. The good effects of the electrical treatment are due to the improved activity of the circulation in the nervous centres, and to the tonic effects of the faradic applications on the muscles. With the electrical may be combined the usual medicinal and hygienic methods of treatment. *Local chorea*, as *histrionic spasm*, *nystagmus*, etc., is sometimes promptly cured by galvanic or faradic applications. When histrionic spasm is of long standing, it is most rebellious to all kinds of treatment, but, if at an early period the irritability of the affected muscles is allayed by galvanism, a cure may be effected. The most promising method consists in the application of a stabile current, the anode resting on the disordered muscles. The seventh nerve should also receive stabile

[1] Medical Electricity, op. cit.

[2] Berliner klinische Wochenschrift, No. 35, 1874.

applications, and the sympathetic ganglia of the corresponding side should also be stimulated. All sources of reflex irritation must be removed. Time is as important as respects the curability of *nystagmus* as of histrionic spasm. Recent cases, not due to intracranial lesions, and purely local in origin, although reflex influences may have excited the muscular disorder, are the most favorable. Cases of *nystagmus*, *acquisitus oscil*, and of the periodical form, have been cured by Soethin[1] and Nieden,[2] by galvanism, the anode resting on the mastoid process and the cathode on the eyelid.

Blepharospasm has been relieved by stabile applications, and the accompanying pain and inflammation also. So much, however, depends on the cause of the reflex spasm that the best results are obtained when the exciting irritation has been removed, the muscle persisting in spasm. A well-moistened sponge electrode—the anode—should rest on the affected muscle, the eye being closed, and the cathode on the cheek below. The current should rise slowly to the maximum, and should be only strong enough to produce faint flashes of light, and should decline without shock.

Torticollis, or *wry-neck*, is compounded of spasm and paresis, but the element of spasm so far preponderates that it is best considered in this connection. The affection has its real seat in the spinal accessory nerve, or in those motor filaments which innervate the sterno-cleido-mastoid and trapezius muscles. The evidence of irritation of a motor nerve trunk is spasm of the muscles to which the nerve is distributed. The spasm may be in the sterno-cleido-mastoid, or in the trapezius, and the head will deviate from its usual and be fixed in the ab-

[1] Wiener med. Presse, No. 47, 1873.

[2] Berliner klinische Wochenschrift, No. 47, 1874.

normal position accordingly. The affected muscles are tense, painful, and rigid. The antagonistic muscles are weak and relaxed. The object of treatment should be to relax the spasm of one set of muscles, and to strengthen the other set. A stabile galvanic current accomplishes the first object when applied to the tense and contracting muscles, and a faradic current effects the second object by stimulating the weak muscles on the other side. It is important to note that strong currents are required in the treatment of these cases. I have usually employed thirty to forty of the elements of Siemens and Halske, and a faradic current of sufficient intensity to throw the weak muscles into very active contractions. The applications should be made daily, and the sittings may be ten minutes—five being occupied with each application. In several instances, when the spasm was in the trapezius, I have seen the head very rapidly straightened by a strong galvanic current interrupted every half minute. In my experience, a cure is readily effected in recent cases of torticollis, when there are no lesions of the spinal cord, or of the vertebra, or of the nerve trunk. Moritz Meyer[1] reports a case cured after a year.

Spasmodic stricture of the œsophagus is usually readily cured by galvanism, Dr. F. F. Frank[2] narrates a case in which a cure of this disease was effected by direct application to the œsophagus, the cathode resting at the stricture. *Singultus* or *hiccough* is often promptly arrested by both currents. The action of the currents is, however, not the same. When galvanism is used, a descending stabile current is passed through the phrenic, the anode being placed over the nerve above the clavi-

[1] Deutsches med. Wochenschrift, No. 18, 1875.

[2] Archives of Electrology and Neurology, vol. ii. p. 23, May, 1875.

cle, and the cathode at the epigastrium. The current is also transmitted transversely through the body so as to include the diaphragm in the circuit. When faradism is used, the principle of inhibition of action is called into exercise. At the moment the spasm is to occur, a strong faradic current is transmitted through the walls of the chest; both impressions arriving at the spinal centre at the same moment, one inhibits the other, and an arrest of action is the result. I have thus succeded at once in arresting hiccough when the galvanic current had been used for hours with but partial relief.

Spasmodic asthma is sometimes remarkably improved by galvanism of the pneumogastric nerves. Neftel[1] reports successful cases, and I have seen very great improvement. Electricity is, of course, adapted to the cases of spasmodic asthma without complications. If such a case is treated during the existence of the paroxysm, by galvanization of the pneumogastric nerve, the difficulty of breathing soon subsides. If the irritability of the end organs of the vagi be relieved by systematic galvanization in the intervals between the seizures, and more frequent applications with the first warnings of an attack, results of a permanent character may sometimes be achieved. The difficulty of breathing occurring paroxysmally in emphysema is sometimes much improved by galvanization. The benefit derived from galvanism is the more obvious, the more the attacks are nervous, and the local condition that of spasm.

Galvanism is one of the numerous remedies employed against *tetanus*. The dictum of Onimus and Legros, that there does not exist in science up to the present a single example of cure of tetanus by means of the electrical current, cannot be accepted without qualification. These authors, however, give full details of a

[1] Galvanotherapeutics, 1871, pp. 161.

case of tetanus cured by the combined administration of chloral and electricity, and which demonstrates the character and degree of the utility of electrical treatment. It was found that during the passage of the current, the contracted muscles were relaxed, to the great comfort of the patient. Chloral calms, produces sleep, but does not relax the contracted muscles. The current is also useful to prevent the fixation of the muscles of respiration and death by asphyxia. The applications should consist of the descending current, to the spine and to the extensor muscles, of medium intensity, and of a duration not greater than an hour or two at a time. The good effects of this mixed method of treatment are sufficient to justify further trials: the same method might possibly prove useful in *hydrophobia*. Dr. Mendel,[1] of Berlin, reports two cases of tetanus, one of the traumatic, the other of the idiopathic variety, cured by galvanization. In the first case, eight cells (Daniell's) were used, the positive pole to the forearm, and the negative to the cervical spine, and in the inferior extremities, the positive pole to the anterior part of the leg and the negative to the lumbar spine. Fifteen minutes was the duration of the applications. In the other case, a cure was effected within ten days by the same mode of application. Dr. Mendel advises a mild current to the affected muscles, the positive pole acting on their antagonists. The effect seems to be due to the influence of the current on the sensory nerves, thus lessening the intensity of the reflexes. Strong currents seem to be less effective than mild, a fact to be borne in mind, since, owing to the violence of the disease, the temptation exists for the use of strong measures.

Writer's cramp, and allied defects, from overuse of certain muscles, are more successfully treated by gal-

[1] Berliner klinische Wochenschrift, September, 1868.

vanism than by any other means. With galvanism must be conjoined rest and systematic gymnastic training. Indeed, without rest no improvement can take place in the condition of the affected muscles. The state of the muscles in writer's cramp varies in different cases. There may be cramp of the muscles concerned in the prehension of the pen; there may be a condition of fatigue and exhaustion, or some of the muscles may be paretic. Some of the cases are local and muscular; some are local and nervous, and a small proportion have their origin in intracranial lesions—in changes in the motor and co-ordinating centres. It is obvious that the treatment must be adapted to the conditions present. As most of the cases are due to muscular fatigue and cramp, the most appropriate remedy is galvanism, but this must be conjoined with rest, massage, and gymnastics. The anode should be placed over the cervical plexus, and the cathode brushed over the muscular groups in turn from the shoulder down. If the defect is confined to the thumb and finger muscles—to the thenar group, the interossei, and flexors of the fingers—the applications should rather be confined to these parts, and consist in the descending labile current. If the lesion consist in relaxation, paresis, and degeneration of any of the muscles, faradism may then be employed with advantage. Duchenne's electrodes are best adapted to cases requiring application to individual muscles. The affected muscles must be selected out, and a current of a strength necessary to induce contractions, merely, passed through them. Under no circumstances ought the muscles be tired, either by the strength or duration of the applications. Treated in accordance with these principles, recent cases of writer's cramp may be cured or ameliorated.

CHAPTER V.

ELECTRICITY IN THE PARALYSES.

The paralyses are referable to one of three groups. to the cerebral, due to disease of the cerebral organs; to the spinal, due to disease of the pons, medulla, or the spinal cord, below; to disease or injury of the peripheral nerves. These anatomical distinctions are not only correct in the anatomical sense, but, also, from the diagnostic and therapeutical point of view. The cerebral paralyses have been sufficiently discussed. The spinal paralyses include the results of inflammation of the meninges and of the cord, and chronic affections—as infantile paralysis, progressive muscular atrophy, and others. For the purposes of electrical treatment, the spinal paralyses may be divided into those with, and those without, loss of faradic excitability, or the reactions of degeneration. Again, some of the paralyses are characterized by rapid wasting of the muscular tissue, and others equally by its preservation.

The diagnostic applications of electricity have been sufficiently set forth; but the reader should bear in mind that the power of the muscles to react to a faradic current is lost in cases of spinal disease when that part of the spinal cord is affected from which the muscles are innervated. When in cases of paraplegia the muscles do not respond to a faradic current, but do respond to a slowly interrupted galvanic current, the disease is situated in that part of the cord supplying the lower extremities with innervation.

Spinal Paralyses.

In *paraplegia* caused by an acute inflammation of the spinal meninges or cord, the electrical treatment should be postponed until all acute symptoms have subsided. Applications must be made to the spine and to the affected muscles. As the objects of the treatment are to remove the products of inflammation, and to improve the nutrition of the cord, a galvanic current should be transmitted through the cord. As the resistance is great, a current of considerable intensity is necessary. A descending stabile current from thirty, forty, or more elements should be passed, the positive pole of large size, well moistened, on the neck just under the occiput, and the negative on the sacrum. If any especially tender points exist on the spine, the positive should be placed on these also. The spinal nerve roots, having an intimate relation to the lesions, ought, also, to be included in the circuit by lateral application of the cathode to each side, taking each nerve in turn, the anode resting on its point of origin. Paralysis of the bladder and rectum, when present, adds materially to the discomfort and increases the peril of the patient; hence it is highly important to restore the functional condition of these organs. I have succeeded, in cases otherwise not amenable to treatment, in restoring control of the bladder and rectum. An effort ought always be made to accomplish this, for a paraplegic, having at the same time incontinence of urine and feces, is not only more liable to bed-sores, but he is an object of disgust to all about him, and is, therefore, likely to be neglected. I have succeeded often with the faradic current, by placing an electrode on the spine, and the other, properly

insulated and terminating in a metallic button, in the rectum and bladder. A properly interrupted galvanic current will accomplish the same purpose. Beside the applications to the spine, the paralyzed muscles should receive attention. If the muscles of the paralyzed members have not wasted, and react in the normal manner, or more readily to the faradic current, their condition cannot be improved by electricity. In cases of disseminated disease, there may be groups of muscles reacting in a perfectly normal manner, and other groups that do not react at all to a faradic current, but with abnormal readiness to a galvanic current. Whilst the former do not, the latter do require electrical treatment. It follows from this fact that in cases of paralysis from spinal disease, the muscles should be carefully examined as to their electro-contractility.

Although in inflammatory affections of the spinal meninges or cord electrical applications are not proper until the acute symptoms have subsided, the same rule is not necessarily binding in respect to the treatment of the muscles. When the tendency to wasting and degeneration of the muscular elements manifests itself, the more promptly the electrical treatment is undertaken, the better. If the muscles do not react to faradism, a galvanic current should be employed, and the muscles exercised with this, until the power of response to the former is restored. A current of sufficient strength merely to cause muscular contraction only is necessary. Pains and hyperæsthesia are removed by galvanism; anæsthesia by the faradic brush. Notwithstanding the rule to avoid the treatment of acute affections of the cord by electricity, Hitzig[1] reports a case in which strik-

[1] Virchow's Archiv, Band xl. p. 455. *Zur Pathologie und Therapie entzündliches Rückenmarks Affectionen*, von Dr. Edward Hitzig in Berlin.

ing results were obtained by galvanization of the spine, of the principal nerve trunks, and of the sympathetic, the applications to the spine being both labile and stabile. Levin reports a similar success. Beginning the treatment on the twentieth day after the onset of symptoms, remarkable improvement resulted from the galvanic applications.

In respect to *chronic myelitis*, there can be no question in regard to the value of electrical treatment. The applications must be made to the spine by large electrodes, the current from 20, 30, 40, even more of the large elements of Siemens and Halske, or of Hill (gravity battery), being necessary to reach the cord. There are two modes in which the cord or affected areas can be reached: by a reflex impression; by a direct excitation. When the surface is mildly irritated, the vessels of the cord change in calibre—probably contract—and the cells in which the peripheral sensory fibres terminate undergo some molecular modification. To this kind of action may be referred the cutaneous irritation of mild faradic and galvanic currents.

The cord may, however, be acted on directly. There is a singular misconception as to the strength of current necessary to do this. The resistance offered by the soft coverings and the bony envelope is very great, and hence very high electro-motive force is necessary to overcome it. From 20 to 30 milleampéres (millewebers), or from 50 to 70 elements, will be required to reach and act on the cord efficiently. As the application of this current-strength by carbon electrodes covered with leather produces intolerable burning, the electrodes used for this purpose should be of large size and covered with sponge. The larger the surface at which a given quantity of galvanism enters the skin, the less painful the application.

The position of the electrodes will be determined by the seat and character of the lesions. If circumscribed, the poles must be placed near each other; and if the longitudinal area of the cord is involved, one pole should be placed on the nape of the neck and the other on the sacrum. There are decided differences of opinion as to the effects of the poles and of the current direction. Onimus and Legros maintain that a descending current increases the blood supply, and that an ascending current lessens it; but the opposite view is held by the majority of those who advocate polar applications. The fact is, probably, as Erb maintains, that the direction of the current has but little influence, and that both poles had better be applied to secure the catalytic effects of both. If there are tender points on the cord, it is good practice to apply the anode to them and the cathode elsewhere, usually on the epigastrium. Besides the direct application to the cord, the ganglia of the sympathetic are stimulated to influence the vaso-motor and trophic centres. This purpose is accomplished by the method known as "central galvanization." The cathode is put on the epigastrium and the anode is placed successively on the top of the head, on the neck, over the sympathetic ganglia, and on the cervical vertebra, and finally on the dorsal vertebra opposite the epigastrium. The duration of the application in chronic myelitis will range from five to fifteen minutes, and the frequency will be determined by the character of the case. I am convinced that in many cases much more permanent and assured results would be obtained by more frequent applications. When the interval is too long, the impression made by one application has ceased before the next begins; they are usually daily, and may often be twice a day with advantage. The whole duration of the electri-

cal treatment must necessarily be very uncertain. To avoid injury by too long, continuous applications, they should be intermitted occasionally.

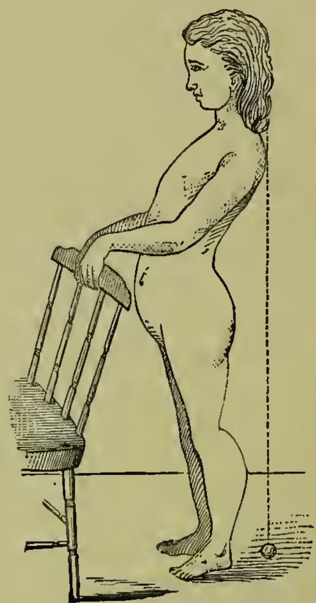
The *séances* should not be longer than a minute or two for the spinal application, but the peripheral nerves must be stimulated also, and the muscles exercised, so that ten minutes or more may be occupied. The treatment of the paralyzed rectum and bladder, by intra-vesical and rectal electrodes, as already mentioned, is an important part of the electrical method. The relief to the pain, tingling, and unrest, in the paralyzed members, is best afforded by stabile and labile galvanic currents, the anode on the spine and on painful spots, and the cathode resting on the peripheral nerves, or brushed over the whole of both members. Coldness, bluish discoloration, dry and scaly skin, and anæsthesia are best relieved by the faradic brush, applied in turn over all of the paralyzed parts. The paralyzed muscles must be treated, as already laid down, by the faradic current, if they respond to it; if not by the galvanic, which is to be continued until the faradic acts. There are now no differences of opinion as to the utility of electricity in chronic myelitis. I have myself seen the most striking results. Erb[1] reports that of one hundred cases treated by it, he obtained a more or less favorable result in fifty-two. Rosenthal[2] speaks in high praise of the good effects of electricity in the paralysis of the bladder and rectum in myelitis. His preference is for an interrupted galvanic current, one electrode placed in the rectum, the other on the hypogastrium. Erb holds that the treatment must be continued for months, and, if necessary, interrupted for a time, to be resumed again.

[1] Ziemssen's Cyclopædia, vol. xiii.

[2] Klinik der Nervenkrankheiten, etc., von M. Rosenthal. Stuttgart, 1875, p. 312.

Infantile paralysis is a typical example of a spinal paralysis, and affords the best evidence, probably, of the good effects produced by electricity. This disease is usually regarded as an affection of the anterior cornua of the spinal cord, the multipolar ganglion cells being also involved.[1] In addition to their motor function, these cells have an important relation to the function of nutrition, and are regarded as "trophic." Besides the paralysis resulting from disease in this part of the spinal cord, the paralyzed muscles waste rapidly, and deformities

FIG. 62.



Pseudo-hypertrophic infantile paralysis.

result in the limbs, spine, and joints. The atrophic degeneration of the muscles begins in a short time, and is very evident in a few weeks. To such an extent is the

[1] Charcot et Joffroy, Archives de Physiologie normale et path., 1870.

wasting carried that the muscles entirely disappear, and the skin rests on the bones. Less frequently the place occupied by the muscles is enlarged by fat and connective tissue, thus presenting an appearance of apparent hypertrophy—whence the name "pseudo-hypertrophic" (Fig. 62). In this disease the reactions of degeneration are perfectly characteristic. As Duchenne[1] first pointed out, in this disease the reaction of the paralyzed muscles to the faradic current declines quickly, and is entirely

FIG. 63.

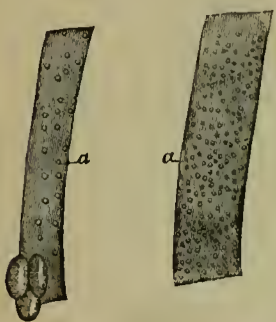


FIG. 64.

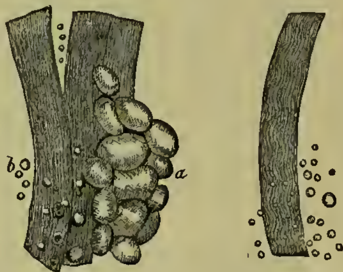
Fatty degeneration of the muscles.

lost by the end of the second week in those muscles severely paralyzed. On the other hand, muscles whose faradic excitability merely diminishes, but does not entirely disappear, regain their contractility to the stimulus of the will, and the more promptly, the less the faradic excitability has declined. Whilst the faradic excitability declines, the muscles manifest an increased readiness of response to galvanism, and contract energetically to a strength of current barely sufficient to move the healthy muscles. This fact, first demonstrated by Hammond,

[1] De l'Electrisation localisée et de son Applications à la Pathologie et à la Thérapeutique. Deux. Edition, Paris, 1861, p. 177.

and nearly simultaneously by Radcliffe, was, it is alleged, somewhat earlier ascertained by Salomon[1] (1868). The reflexes are extinguished in this disease, but the sensi-

FIG. 65.

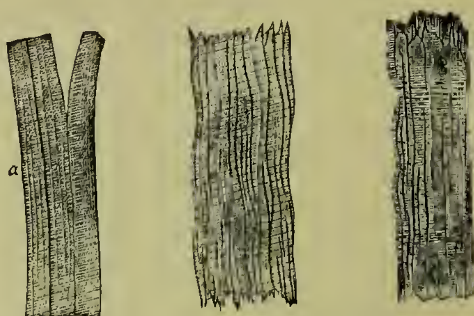


Fatty degeneration of the muscles.

bility of the skin is not impaired. The rectum and bladder continue to functionate normally.

The electrical treatment consists in spinal and muscular applications, and the earlier it is undertaken after

FIG. 66.



Fatty degeneration of the muscular elements in infantile paralysis.

the termination of the fever, the better for the future of the patient. Old cases have proved so rebellious to the treatment as to cast discredit on the electrical method. To the spine large sponge-covered electrodes are ap-

[1] Jahresbericht d. Kinderkrankheiten, vol. i. p. 1868.

plied, so as to include the diseased area, and by the stabile method. The affected muscles, responding to the galvanic current only, must be acted on by this current until the power of reaction to faradism is restored. Each muscle must, in turn, be made to contract several times at each sitting, but fatigue must be avoided. Placing the anode over the spine, at a point corresponding with the highest level of the disease, the cathode is passed over the affected muscles in turn below, making each one contract several times. When the contractility to faradic stimulation is restored, the electrodes of the faradic battery are applied to the muscles by the direct or indirect method, until the reactions become normal. It cannot be too strongly insisted on, that the treatment of this disease demands the utmost patience and the most protracted perseverance. Unless the parents, and the patient, consent to give the necessary time and attention to the treatment, it were better not to undertake it. Many months, even a year or two, may be required. Cases of long standing, in which deformities have occurred, are hopeless. When the muscles are simply wasted, the case otherwise being favorable, a cure may be expected by sufficiently extended treatment, provided, there is still muscular tissue to react to the galvanic current. There can be no doubt as to the value of electrical treatment in suitable cases. With faradism alone, Duchenne[1] was able to effect a cure in a considerable proportion of cases—of those in which the faradic excitability was lessened, but not entirely wanting. Faradism could hardly be beneficial in cases so far damaged that the muscles cannot be made to contract by the strongest current. Onimus et Legros[2]

[1] De l'Electrisation localisée, op. cit.

[2] Traité d'Electricité médicale, op. cit., p. 490.

strongly condemn the faradic applications, and insist on the superiority of galvanism. They hold that the good effects are not due to muscular contractions, but to the influence of the galvanism over the circulation, and secondarily over nutrition, and over the trophic system. They make applications to the cord and to the peripheral nerves. The anode rests on the spine just above the seat of the lesions, and the cathode on the trajectory of the nerves passing to the paralyzed muscles, "maintaining on the cord, without interruption, during three to five minutes, a descending current from ten to twenty elements." The muscles are also acted on directly by labile applications. The whole duration of each *séance* is twenty to twenty-five minutes, and it should be held three or four times a week, for many weeks, intermitted occasionally, to be resumed again. In recent cases, *Onimus et Legros* say, that "remarkable results" are obtained by their method. English authorities are equally positive as to the good effects of electricity in infantile paralysis. Thus Reynolds[1] expresses himself in the treatment: "that, in all cases, the electrical and gymnastical parts of the treatment are of primary rather than of merely secondary importance, I am every day more and more convinced, because every day I meet with instances of muscles, which I should have once looked upon as hopelessly paralyzed, being resuscitated by those means." The German authorities, also, maintain the superiority and success of the electrical treatment (Benedict,[2] Ziemssen,[3] Eulenburg,[4] and others).

[1] A System of Medicine, H. C. Lea's Son & Co., 1879, vol. iii. p. 1007.

[2] Electrotherapie (erste Hälfte, 1874), Wien, 1868.

[3] Die Electricität in der Medicin.

[4] Lehrbuch der functionellen Nervenkrankheiten, etc., Berlin, 1871, pp. 607 and 620.

Progressive muscular atrophy, which presents many points of analogy to infantile paralysis, differs from the latter in respect to the curative power of electricity. The actual seat of the primary anatomical changes is much disputed. There are two principal theories and a minor theory. The first and most authoritative theory is that the initial lesion is situated in the anterior cornua, especially affecting the multipolar ganglion cells which undergo atrophic degeneration and disappear. As a result of this lesion, and as we have found is the case in infantile paralysis, the muscles innervating from a diseased part of the cord waste, and ultimately their proper anatomical elements disappear. Cruveilhier[1] was the first to give a correct account of the grosser anatomical changes, but the first really accurate studies of the microscopical lesions in the cord were made by Charcot et Joffroy[2] and Lockhart Clarke.[3] These studies demonstrated the constancy of the alterations in the anterior cornua of the spinal cord, and especially in the multipolar ganglion cells. These cells, as has been already mentioned, are concerned in the maintenance of the nutrition of parts with which they are anatomically connected. When these cells undergo wasting and disintegrate, the nutrition of the muscles declines and they ultimately entirely disappear. In cases of paralysis to an equal degree from disease of other parts of the cord, the muscles do not undergo atrophic changes to anything like the same extent. The next most important theory locates the initial changes in the muscles. From the affected muscular elements, the disease extends to

[1] Arch. Général de Méd., Mai, 1853, p. 561, and Janv. 1856, p. 1.

[2] Archives de Physiologie normale et pathologique, Paris, 1869, vol. 11, p. 356.

[3] Medico-Chirurgical Trans., vol. 51, p. 249.

the intra-muscular nerves. Thence by an ascending neuritis the cord is ultimately reached. The most recent and powerful advocate of this view is Friedreich.[1] The least influential theory is that which regards the sympathetic system as the seat of the primary changes. The advocates of this view are Schneevogt[2] and Eulenburg and Landois,[3] chiefly. Which theory, soever, we may adopt, it is obvious that electricity must be applied both to the spinal cord and to the muscles, for both in cases well advanced are diseased. To the cord descending stabile currents should be applied, and from the cord outwardly along the trajectory of the nerve trunks supplying the affected muscles. Faradic and galvanic applications to the wasting muscles are of great importance. Hitherto electrical treatment has produced no results in progressive muscular atrophy. As sanguine as Duchenne is in regard to the curative powers of localized faradic applications, he frankly confesses their inutility in this malady. More recently much more favorable results have followed the systematic and persevering use of the galvanic current applied to the cord, to the muscles, and to the sympathetic by the method known as central galvanization. A case of advanced muscular atrophy has been reported cured by central galvanization alone, in the hands of Nesemann.[4] Good effects have been reported by Benedict,[5] Erb,[6] and others, by the combined treatment above mentioned. I have

[1] Ueber progressive Muskelatrophie, etc., von Dr. N. Friedreich, Berlin, 1873.

[2] Quoted by Friedreich. Supra.

[3] Die vasomotorischen Neurosen. Wiener med. Wochenschrift, 1867 u. 1868. Separatabdruck, also.

[4] Quoted by Eulenburg, Ziemssen's Cyclopædia, vol. 14, p. 150.

[5] Electrotherapie, op. cit.

[6] Quoted by Friedreich. Supra.

seen one case apparently entirely arrested and the wasted muscles in part restored by the persistent use of strong galvanic and faradic applications in alternation. When the muscles cease to respond to a faradic current, the galvanic must be used, and of sufficient strength to develop reactions. In all cases, the galvanic should be used in alternation with the faradic current, because of its greater influence over the function of nutrition.

I include in one group the scleroses of the cord, *multiple sclerosis*, *antero-lateral*, and *posterior spinal sclerosis* (progressive locomotor ataxia). Although these are not strictly paralyses, they are accompanied by more or less paresis, by incoördination of muscular movements, an apparent paralysis, and the principles and plans of electrical treatment are the same as in the group of paralyses. The electrical applications, in accordance with the fundamental principles, are made to the spine and to the peripheral nerves. Both forms of currents are used. A descending stabile current from twenty to forty elements is made to the spine daily, and labile applications from ten to twenty elements are directed to the painful points. For the anæsthesia of the feet and limbs, the faradic brush is most serviceable. I have seen excellent results in posterior spinal sclerosis from the persistent use of mild, rapidly interrupted faradic applications to the spine and limbs daily for a few minutes, but no cures, only amelioration. Strumpf,[1] of Dusseldorf, has recently had remarkable results from the persistent use of the faradic brush. He gives the details of a case which was arrested in the second stage, the man returning to work, but the "knee jerk" continued absent. He reports other cases equally successful, but he is awaiting the results of time. The method consists in brushing with

[1] Neurologisches Centralblatt, No. 1, 1882.

the wire-brush over the spine, thighs, and limbs for several minutes daily, using a current of moderate strength. Before applying the brush, the skin must be dried well. The application must be thorough and persevering, and its duration about fifteen minutes daily. The mechanism must consist in the reflex action. Strumpf has found that faradic brush stimulation of one side will cause an elevation of temperature of the opposite corresponding side. It is probable that the peripheral stimulation promotes the nutrition of the cord. Symptomatic treatment is very serviceable. The diplopia, incontinence of urine and feces, and pains may be very much relieved by faradic and galvanic application. In progressive locomotor ataxia, more favorable results are attainable by rest, hydrotherapy, and galvanism, than by any other means; and of these, galvanism is the most important. The patient applying for treatment should be informed of the probable duration of the case, and the necessity for protracted applications extending over years. In some rare cases, electricity aggravates all the symptoms; when this occurs it should not be persevered in. It sometimes happens that very mild currents do better; again, the strongest currents are most serviceable. The applications should be modified accordingly.

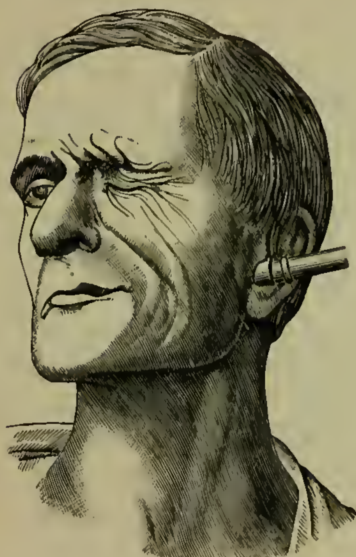
Peripheral Paralysis.

Peripheral paralyses take their name from the situation of the lesions in the peripheral motor nerves. They consist of the so-called rheumatic inflammation, of neuritis, whether idiopathic or secondary, and of cases of traumatic injury to the nerve. The diagnostic relations of the subject have been fully considered elsewhere;

we have now, therefore, the therapeutical questions for solution.

The type of a rheumatic paralysis is that form of *facial paralysis* due to the impression of cold on the facial nerve—the seventh—after its emergence from the foramen, and where its ramifications form the *pes anserinus* (Fig. 67). A current of cold air directed against

FIG. 67.



The muscles innervated from the seventh nerve—the facial—stimulated by a faradic current.

the side of the face induces such a refrigeration of the nerve as to impair its conductivity. Paralysis suddenly ensues in all the muscles innervated by the nerve, the muscles of expression; that side of the face is blank and motionless, the naso-labial fold is obliterated, the eye cannot be closed, and hence, whilst the sound side exhibits all the varied and individual expressions of the human countenance, the affected side is utterly without

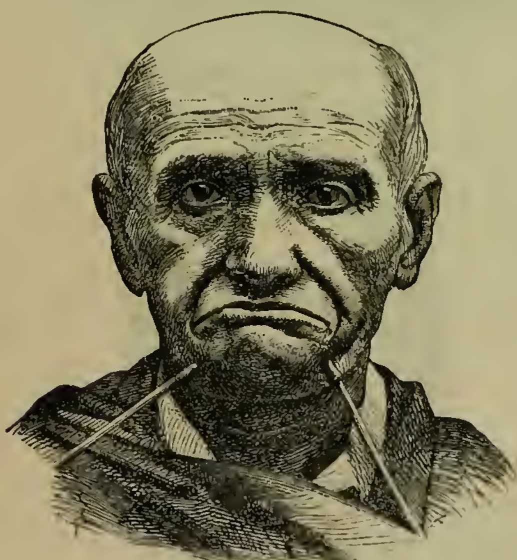
the power of expression. This condition may be slight and exist for a few days, or it may be severe and continue for months and years. A small proportion manifest a tendency to spontaneous cure—the paralytic symptoms gradually declining without treatment, but an abnormal tardiness to react to the various emotions and feelings is apt to remain. If the case is a severe one, the muscles presently exhibit the reactions of degeneration—do not respond to a faradic, but do respond with abnormal readiness to a galvanic current. In the mildest cases the reaction to faradism may be simply diminished and not wholly lost. In those cases arising from the impression of cold, some effusion probably takes place in the sheath of the nerve. Hence the best results may be expected to follow the application of galvanism. A descending stabile current may be applied, the anode resting on the *pes anserinus*, and the cathode on the peripheral portions of the nerve. Ten to twenty elements suffice. When the muscles are to be acted on, after a few days, labile currents are applied by small olive-shaped electrodes, each one or each group in turn receiving attention. The stabile galvanic applications can be made at once, the object being to cause absorption of the effusion, but excitation of the muscles should be postponed for a few days. As a very weak galvanic current slowly interrupted induces ready response on the part of the paralyzed muscles, it is unnecessary to employ a strong current. The muscles should be exercised daily for a few minutes at a time, but not long enough to induce fatigue. Many of the cases recover in a few weeks; some require months, even years, of treatment. I have seen an obstinate case cured after two years of faithful electrical treatment. Cases of many years' standing have been cured by persistent

applications. After a more or less protracted treatment by galvanism, the power of response to faradic stimulation is restored, when this can be employed to complete the cure.

Recently Dr. Ballet[1] has reported cures of facial paralysis by static electricity—by the bath and drawing sparks from the area of distribution of the seventh. The interrupted current of static electricity is an efficient substitute for faradism when it is desired to act on the muscles.

The illustrations which follow, from Fig. 68 to Fig. 76, inclusive, demonstrate the chief movements of the muscles of expression, innervated by the seventh nerve, and

Fig. 68.

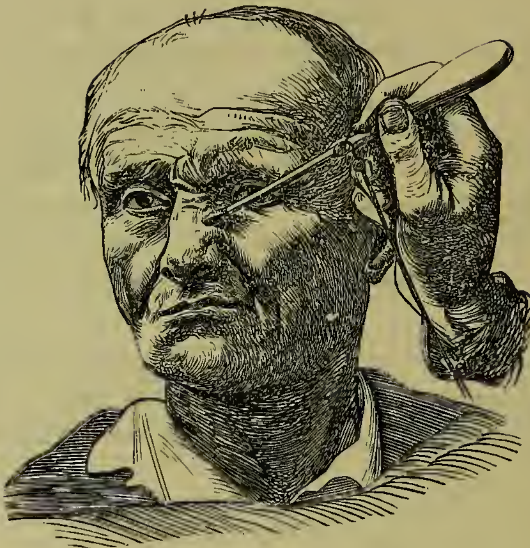


Quadratus menti.

indicate the position of the electrodes when the muscles are to be thrown into action by faradic or galvanic stimulation.

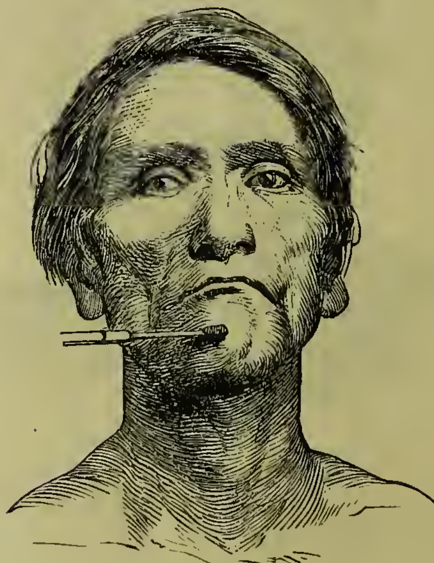
[1] Progrès Medicale, 23–30 Avril, 1881.

FIG. 69.



Levator labii superioris alæque nasi.

FIG. 70.

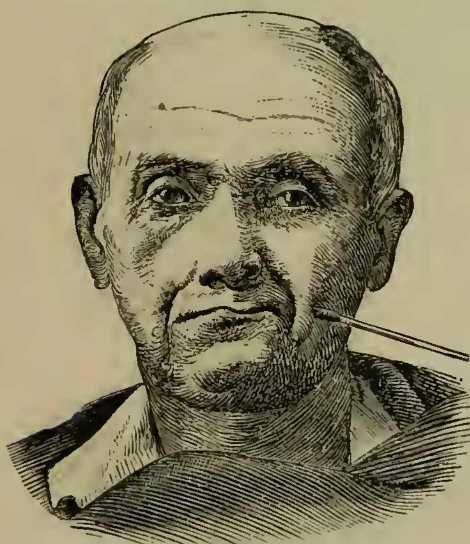


Levator menti.

FIG. 71.

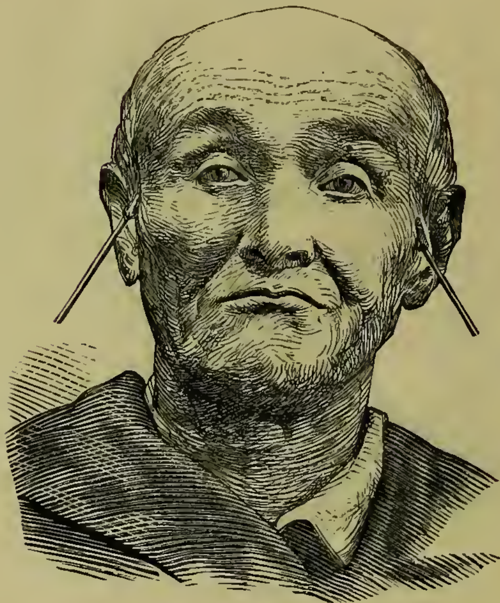
Zygomaticus minor.

FIG. 72.



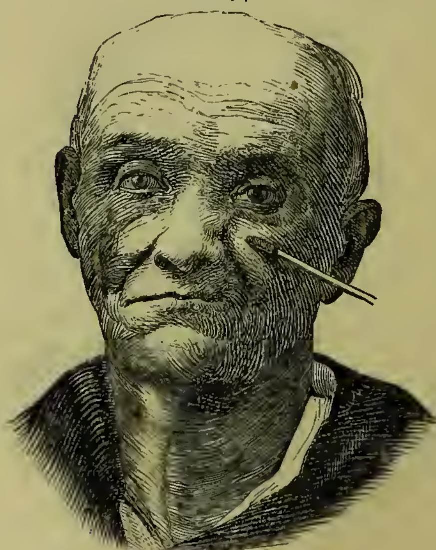
Buccinator.

FIG. 73.



Frontalis.

FIG. 74.

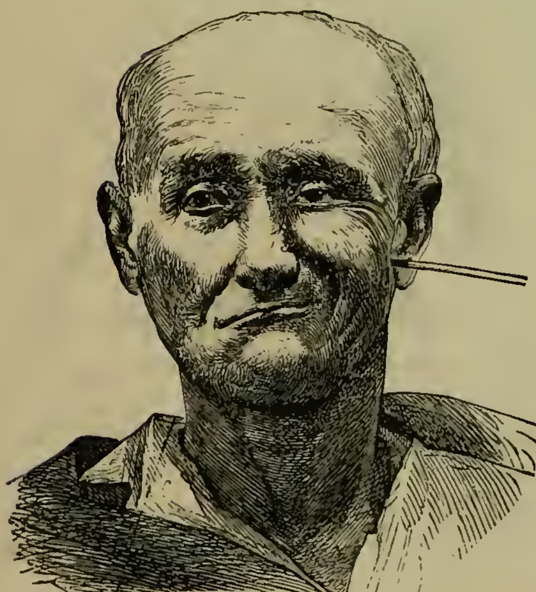


Proprius labii superioris.

FIG. 75.

Levator menti.

FIG. 76.



Zygomaticus major.

The so-called rheumatic paralyses occur elsewhere, but very infrequently. Superficial nerves, as the ulnar and radial, and anterior and posterior tibial, are rarely affected in the same way as the facial and with the same symptoms. The plan of treatment is also the same. The seventh nerve is also rarely injured by the forceps in delivery, and the infant consequently suffers from paralysis of that side of the face. More frequently the seventh is invaded in the aqueduct of Fallopious by disease of the middle ear producing caries of the bone.

FIG. 77.

Paralysis with atrophy of the muscles of the left shoulder. (HAMILTON.)

Inflammation is excited in the nerve, and its elements are disassociated and softened. The condition of the muscles is determined by the amount of injury done to the nerve. In these cases, also, are represented the

reactions of degeneration in the nerve and muscles. The power of response to the faradic current is quickly lost, and an abnormal readiness of contraction on galvanic stimulation is developed. The muscles also waste, and great deformity is the final result. When the nerve is destroyed by the suppurative inflammation, the case is hopeless, as regards cure and the restoration of the consentaneous action between the volitional impulse and the muscular movement. The condition of the muscles may be improved by persistent use of an interrupted galvanic current, but the supremacy of the will is permanently lost. When restoration of the nerve takes place, the muscles at first react only to the interrupted galvanic current; after a time the faradic will excite them, as above stated. The position of the lesion, whether in front or behind the origin of the chorda tympani, is ascertained by the state of the palate and uvula, and the condition of the sensibility in the corresponding half of the tongue. In these cases, as in the examples of merely rheumatic inflammation, but to a greater extent, is persistence in the treatment necessary. Stabile and labile applications should be made, a strength of current being employed merely necessary to induce muscular action in the paralyzed muscles. An olive-shaped electrode—the anode—well covered with soft leather and thoroughly moistened, may be placed nearest the nerve by resting on the anterior border of the external auditory foramen. A carbon electrode, of button shape, and well covered with soft sponge—the cathode—may be placed at various points on the peripheral distribution of the nerve, and held in position for a few seconds, and then removed to another point, until, in turn, the whole expansion of the nerve has been acted on. Daily *séances* of five to ten minutes should be persisted in for

months, and years if necessary, intermissions being allowed for a few days at a time.

Various motor nerves subjected to injury, paralysis ensues in the parts innervated by them. Thus, the pressure of a crutch, a severe blow, a penetrating or gunshot wound, may each by injury to nerve trunks induce more or less extensive paralysis, according to the importance of the nerve or nerves injured. The reactions of degeneration ensue in such cases, both in the nerves and muscles, but they are not the same in both. As regards the nerves, the irritability to both faradic and galvanic currents lessens gradually when the paralysis occurs, and at the expiration of one or two weeks has entirely disappeared. If the nerve undergoes degeneration, or cure, after a time, the galvanic excitability

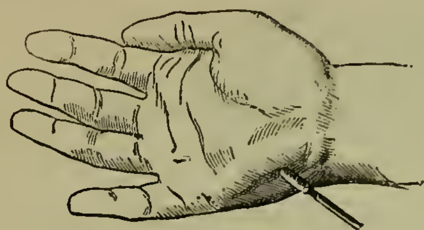
FIG. 78.

Paralysis and atrophy of first dorsal interosseous muscle.

is slowly restored, beginning from the central portion and extending peripherally, and afterward the faradic excitability; but the reaction to the stimulus of the will precedes the electrical; in other words, voluntary motion is restored before the nerve reacts to the currents (Fig. 78). The behavior of the muscles has been already described; the faradic contractility disappears, and an abnormal readiness to contract to galvanism is devel-

oped. After a time the galvanic excitability declines to normal, and the faradic excitability is restored. We owe these important observations on the phenomena of the reactions of degeneration to Erb.[1] There is universal agreement as to the value of electricity in the peripheral paralysis, to restore the muscles, and to prevent deformity (Fig. 79). Duchenne[2] especially details many examples of wasting and deformity of the members, restored by suitable electrical treatment (Fig. 79). He

FIG. 79.



Stimulation of the hypothenar group.

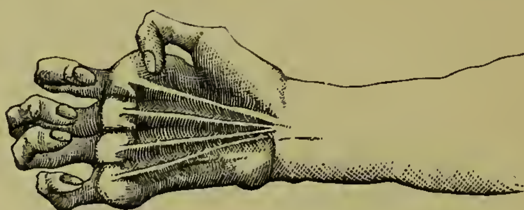
prefers as is usual the faradic applications. He admits that those muscles whose electric contractility is but little affected recover speedily under faradic treatment, but that muscles having lost their power of response to the faradic current soon undergo atrophy. He advises faradization, using at first strong rapidly interrupted currents, the applications being ten to fifteen minutes in duration, daily, and afterwards weaker currents (Fig. 80). Although Duchenne achieved very great results by faradic treatment, his practice was the less efficient because of his persistent opposition to galvanism. He was on the verge of discovering the facts subsequently ascertained by Erb, regarding the difference in the reactions of nerve and muscle, and the reactions of degeneration

[1] Deutsch. Archiv für klin. Medicin, vol. iv.–v., 1868.
[2] De l'Électrisation Localisée, op. cit.

in general. Besides the special electrical authorities who may be supposed to have predispositions in favor of their remedy, Rosenthal,[1] Erb,[2] Eulenberg,[3] and others, as strongly maintain the utility of electricity in these cases.

Under this head should also be included *paralysis of the ocular muscles*—innervated by the third, fourth, and

Fig. 80.



Atrophy and contraction of the muscles of the hand.

sixth nerves, causing various deviations of the ocular globe, and corresponding disorders of vision. The current used should be determined by the electrical reactions of the muscles. As these may be examples of peripheral paralysis corresponding to that of the seventh, and known as rheumatismal, or due to inflammation of the nerve trunk induced by pressure of a neoplasm, the current most likely to be of service is the galvanic. Wecker[4] recommends the employment of six to eight elements in the beginning of the treatment, to be gradually increased to twelve, as the sensibility of the skin lessens. The positive pole is placed at the supra- or infra-orbital foramen, according to the position of the muscle to be acted on, and the negative—an olive-shaped electrode—is passed over the eye—the lids being closed

[1] Klinik der Nervenkrankheiten, p. 661.
[2] Ziemssen's Cyclopædia, vol. xi. p. 423 et seq.
[3] Lehrbuch der functionellen Nervenkrankheiten, p. 363, op. cit.
[4] Thérapeutique Oculaire, Paris, 1879, p. 704 et seq.

—in the direction of the paretic muscle. This indirect or reflex method has quite taken the place of the direct stimulation of the muscles, and it has the further advantage of giving but little pain. According to Wecker, the electrical treatment produces very satisfactory results (*produire des résultats tres-satisfaisants*) (p. 706).

Hysterical Paralyses.

The hysterical paralyses form a distinct group, and are incidents of the hysterical state. They may occur in any voluntary organ, but are usually in the larynx, or upper or lower extremities, notably the last. They occur suddenly without any preliminaries except the complexus of hysterical symptoms. The diagnostic peculiarities presented by them are, the absence of wasting or degeneration, absence of all electro-sensibility, with entire preservation of electro-contractility—the muscles responding with the normal promptitude to the faradic and galvanic currents. The separation of these from all other forms of paralysis cannot therefore be difficult. Without the aid afforded by electrical examination, however, hysterical paralysis might be very difficult of recognition.

The treatment by faradization rarely fails to succeed. It not unfrequently happens that a single *séance* removes a long-standing paralysis, but on the other hand protracted treatment may be necessary, especially when from long disuse the muscles have wasted.

In *hysterical aphonia* there are two methods of procedure which may be tried, the simpler first. The larynx may be stimulated by direct application, the electrodes resting on either side of the organ, and a succession of shocks transmitted by the faradic, or an

interrupted galvanic current. The muscles of the larynx may be reached, also, by placing the anode over the course of the recurrent laryngeals, and the cathode over the larynx, and interrupting the current by cathodal opening and closing. The larynx, however, may be much more effectively acted on by the intra-laryngeal electrode. This procedure is to be preferred in cases of aphonia due to paresis or paralysis of the vocal cords, but in hysterical aphonia the mental impression made by faradic applications is an important factor in achieving a curative result, and may be as decided by external as internal applications.

In *hysterical paralysis* of the extremities, the group of muscles refusing to do duty can be exercised by the faradic current, and as sensibility to the current is wanting, strong applications can be made. In this instance especially the temptation to use powerful currents is great, but it should be restrained, since to fatigue and exhaust the muscles can only do harm. The cutaneous and muscular anæsthesia which accompanies hysterical paralysis can be removed by the faradic brush. The skin should be thoroughly dried, and the brush drawn over the parts to be acted on. In the treatment of this affection, massage and suitable hygienic and tonic medication should be enforced, and massage especially when the muscles long diseased have atrophied.

A similar paralysis occurs in a group of spinal muscles on one side, which, if it continue for months and years, leads to wasting of the paralyzed muscles, and to overaction and spasm of the antagonistic muscles, on the other side. Very great deformity may be thus prόduced, and often caries of the vertebra is diagnosticated and treated, to the serious injury of the patient. The electrical treatment is of the greatest service in such

cases. The paretic and wasting muscles should be daily faradized with a strength of current sufficient to cause active muscular movements, and the overacting antagonistic muscles should have their irritability reduced by a stabile galvanic current from ten to twenty elements. As in these cases, also, tender points exist on the spine in various situations, they should be treated by the anode resting on them, and the cathode on the periphery of the corresponding spinal nerves—a stabile current passing for two to three minutes at each place. Central galvanization, and the general electrization of Beard and Rockwell, may be advantageously combined with the other methods. The success of the treatment is the greater if at the same time the nutrition of the patient is improved by a suitable diet and regimen.

The hysterical state attains its highest pathological expression in *hemianæsthesia*, *hystero-epilepsy*, and the allied states. Although the diseases of a convulsive character have been discussed elsewhere in the therapeutical section, hystero-epilepsy was not included, for the phenomena present in one of these attacks are hysterical and not epileptic. The paralysis of sensation in hemianæsthesia is very readily transferred, as is well known, by various metals and other objects. Faradization with the electric brush promptly removes it. The attacks of hystero-epilepsy are usually quickly terminated by sufficiently powerful faradic stimulation, so timed as to overcome the muscular rigidity of the paroxysm (Fig. 81). Galvanization of the spine, the anode resting on the tender spot, is of great service in removing the excessive mobility—the explosive irritability—of the nervous system, if carried out faithfully during the interval between the seizures. The ovaries should also be carefully galvanized, by external electrodes so

placed as to include them in the circuit, or by a vaginal and an external electrode, also arranged to include the ovaries. To the local treatment should be joined central galvanization, and galvanization of tender spots on the spine.

Since the observations of Charcot, Arthius, and Vigouroux have been published, static electricity has been employed very generally in the treatment of the hysterical paralyses. The reader is referred to the chapters on Magnetism and Statical Electricity for full information on the use of these modes of the electrical force in various hysterical affections.

FIG. 81.

Hystero-epilepsy. (HAMILTON.)

DIPHTHERITIC PARALYSIS.

The paralyses succeeding to diphtheria may be limited to the muscles of the pharynx, or of the eye, or involve the muscular system of animal life in general. The contractility to the faradic current may be diminished or lost—usually and in recent cases merely diminished. More or less wasting of the paralyzed muscles ensues when the paralysis has existed for some time,

and in that case the electro-contractility declines. Galvanism is more serviceable than faradism, because of its influence over nutrition. With local excitation of the paralyzed muscles should be conjoined central and sympathetic galvanization. When the pharynx is affected soon after the morbid process has ceased—but to the severity of which it does not bear a constant ratio—the palate is seen to hang limp and lifeless, the voice has a thick, stuffy, and nasal tone, and, in the attempt to swallow liquids, they are returned through the nose. An insulated button electrode—the anode—should be placed against one extremity of the soft palate, and a corresponding one—the cathode—at the other extremity, and a mild (3 to 5 cups) current interrupted slowly should be transmitted for a few minutes daily. The eye muscles should be stimulated in the mode already described. The muscles of the extremities paralyzed, or in a paretic condition, should be in turn acted by an interrupted galvanic current—the anode placed on the spine, and the cathode passed over the whole of the extremity affected. When individual muscles or groups are paralyzed, smaller electrodes must be employed to select out the muscles requiring stimulation, and the current confined to the parts affected. Very prompt action is demanded in the cases of paralysis affecting the respiratory organs. If the epiglottis and larynx are involved, suffocation may be brought on in the attempt to swallow, or, escaping this danger, foreign bodies may be lodged in the lungs, exciting a fatal pneumonia. Direct galvanization of these organs may render very important service. When paralysis invades the organs of respiration, the pneumogastrics, phrenics, and the cervical plexus on both sides, and the muscles should be faithfully galvanized. Other remedies than electricity

may be used with success, it is true, but the best results are obtained by the timely application of galvanism. If the symptoms are urgent, electricity should certainly be used, in addition to other means. In the absence of proper galvanic appliances, faradism may be substituted.

The above observations on paralysis following diphtheria are equally true of paralysis following other acute diseases.

Lead Paralysis.

Paralysis by lead usually takes the form of "dropped wrist," but it may also occur as paraplegia, hemiplegia, general paralysis, etc. In paralysis of the forearm, the symptoms pursue with considerable uniformity a defined course—a knowledge of which will aid in diagnosis. First, the extensor communis digitorum is invaded; next, the extensor indicis; then the ulnar and radial extensors of the wrist, and ultimately the thenar muscles (the ball of the thumb). After a time the flexor muscles of the forearm and the triceps and the deltoid become weak and paretic. In consequence of the relative weakness of the extensors as compared with the flexors of the forearm, should paralysis affect both in an equal degree, the over-action of the flexors would bring about dropping of the wrist. The electro-contractility declines as the paralysis increases; more or less wasting of the muscular elements takes place, and ultimately the responses to both currents cease, and the muscles disappear, being replaced by connective tissue and fat. For a period before the final disappearance of the electro-contractility, the muscles respond only to a slowly interrupted galvanic current.

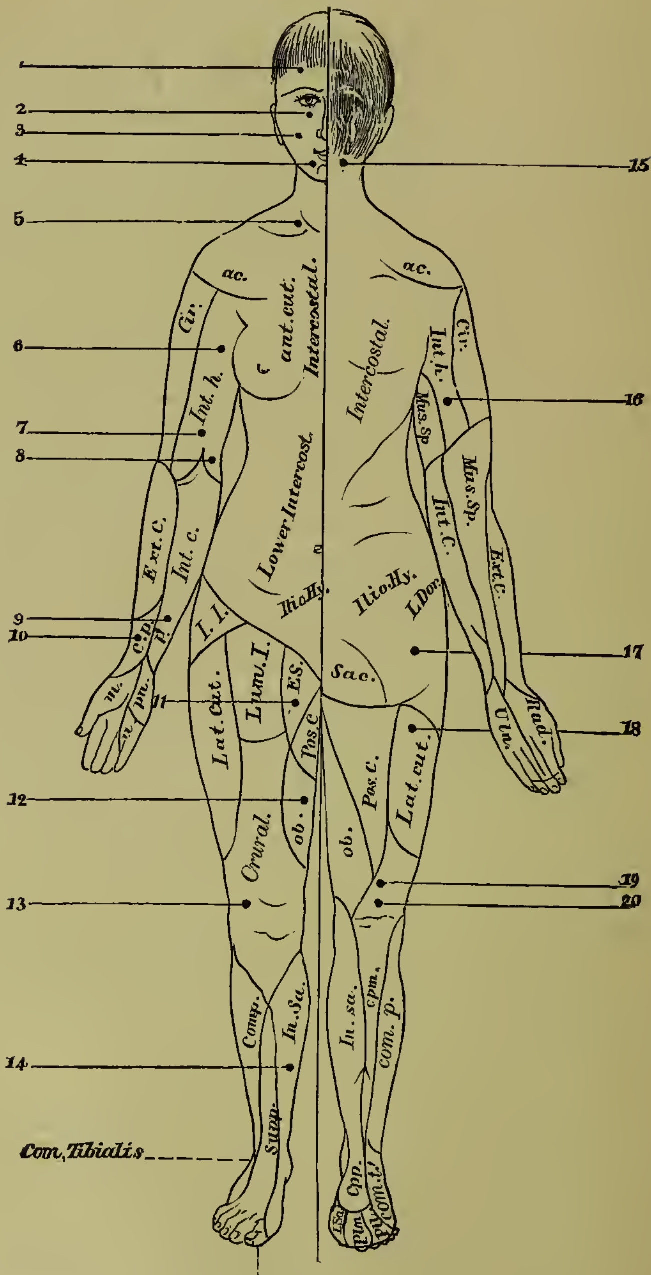
The electrical treatment consists in galvanic applica-

tions by the labile method. When the whole arm is involved, the anode is placed over the cervical plexus, and the cathode is passed over each muscular group in turn. The interruptions consist, therefore, of cathodal opening and closing. When the extensors of the fore-arm are alone affected, the applications to the muscles should be by the indirect method; the anode resting on the motor nerve, and the cathode on the belly of the muscle or on the muscular group. If the muscles have not yet lost their power of contraction to faradic stimulation, galvanism should nevertheless be preferred. The power of diffusion possessed by the galvanic current and its effect on the vermicular motion of the arterioles, and secondarily on the function of nutrition, render it more useful in lead poisoning than is faradism. Faithful and persevering treatment is necessary to procure the best results. Notwithstanding the unquestionable utility of electricity, it should not be relied on to the exclusion of all other treatment, including the agents of elimination. The iodides and bromides to form soluble combinations, and to procure elimination by the kidneys, strychnia to excite muscular action, and massage, are important aids in obtaining curative results, but galvanism is the most necessary of all the remedies.

In that form of lead paralysis manifested in colic, Dr. Rothe[1] has had admirable results from the application of faradic electricity when other powerful means had failed.

[1] Memorabilien, No. 8, 1880.

FIG. 82.



Motor points, and distribution of nerves on the superficies.

1.	Seventh or facial nerve filament	supplying the	Frontal muscle.
2.	" " "	"	Levator labii superioris alæque nasi.
3.	" " "	"	Zygomaticus minor.
4.	" " "	"	Orbicularis oris and quadratus menti.
5.	Phrenic nerve	supplying the	Diaphragm.
6.	Musculo-cutaneous nerve	"	Biceps, brachialis, etc.
7.	" nerve	"	Brachialis internus.
8.	Ulnar nerve	"	Muscles of forearm and hand.
9.	Radial nerve	"	Flexors of thumb and fingers.
10.	Ulnar nerve	"	Palmaris brevis, abductor digitor. min., opponens digitor. min., etc.
11.	Obturator nerve	"	Sartorius, adductor longus, etc.
12.	Crural nerve	"	Adductor longus, vastus internus, etc.
13.	"	"	Vastus externus.
14.	Musculo-cutaneous nerve	"	Flexor digitorum com. long.
15.	Occipital nerve	'	Posterior neck muscles.
16.	Circumflex nerve	"	Triceps, etc.
17.	Intercostales nerve	"	Lumbar muscles.
18.	Gluteus nerve	"	Adductor magnus, etc.
19.	Popliteal nerve	"	Gastrocnemius externus.
20	" nerve	"	Soleus.

CHAPTER VI.

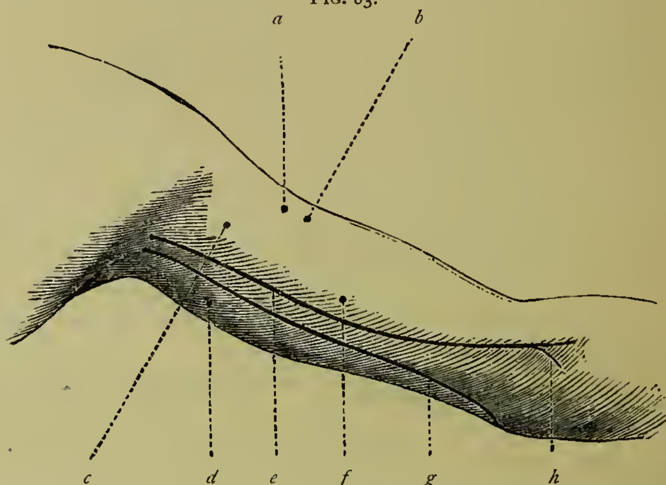
ELECTRICITY IN THE TREATMENT OF PAIN.

There is no fact more certain than the power of galvanism to relieve pain. A rapidly interrupted, high tension, faradic current has to a much less extent the same power. Galvanism can relieve pain when it has no effect on the cause of it, so that its pain-relieving power is an inherent quality. The physiological actions of galvanism do not explain this property, for, although a descending stabile current allays irritability, and an inverse current increases it, in practice the direction of the current seems of little moment, pain being relieved in what direction soever the current is passing. It is, how-

ever, good practice to apply the anode to painful spots. The seat of pain should, of course, be included in the circuit, under any circumstances.

In *neuralgia of the fifth nerve*, tic douloureux, or simple neuralgia, the galvanic current affords relief, but is rarely more than palliative. Besides the fact that tic douloureux is often caused by lesions that cannot be removed—an exostosis for example—the nerve lies so deeply that the influence of the current is dissipated before reaching it. Curative results are sometimes obtained in cases of irritability of the submaxillary, of the infra- and supra-orbital divisions of the fifth, due to cold,

FIG. 83.



a. Musculo-cutaneous. *b*. Biceps. *c*. Musculo-cutaneous. *d*. Cap. intern. mus. tricipit. *e*. Median nerve. *f*. Brachialis internus. *g*. Ulnar. *h*. Branch of median.

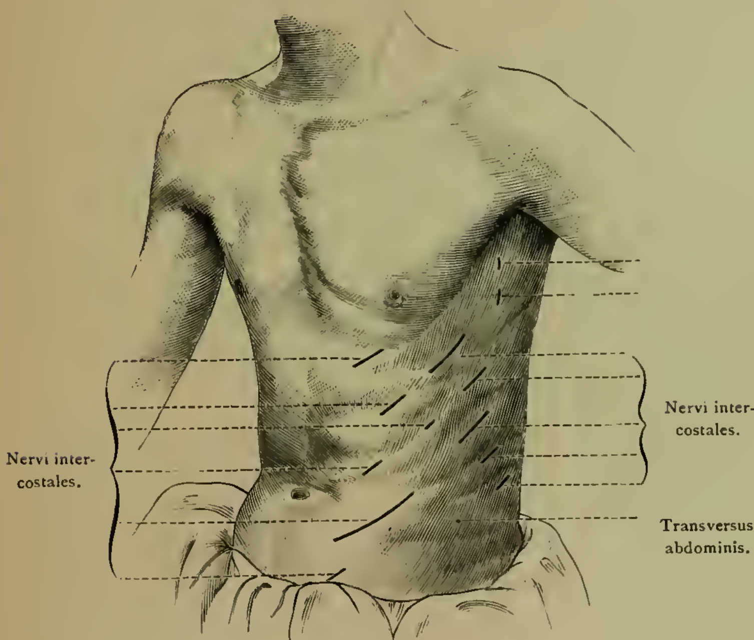
carious teeth, etc., the pain persisting after the cause is removed. It is true, in the main, that galvanism is merely palliative in neuralgia of the fifth. This opinion is supported by Anstie,[1] Benedict,[2] and other observers.

[1] Neuralgia and its Counterfeits, p. 200 et seq.

[2] Electro-therapie, op. cit.

Far different is the effect of galvanism on *cervico-brachial neuralgia.* In a considerable experience in the treatment of this form of neuralgia, which includes cases treated by all the most improved methods except galvanism, but including subcutaneous injection of morphia, I have rarely failed to effect a cure. Close attention must be given to the cases, and sufficient time. The

FIG. 84.



Nerves affected in herpes zoster.

usual error consists in too infrequent applications. The best results are obtained from *séances* of five to ten minutes duration, repeated three times a day, certainly twice a day. The anode is placed over the cervical plexus, and should consist of a large sponge electrode well moistened with hot water; the cathode, of similar

form, should be slowly passed over the shoulder, arm, and forearm. If the case is recent, from ten to twenty elements will suffice, but if old, from twenty to forty elements will be necessary. Onimus and Legros[1] insist on the importance of employing a current of considerable tension, but having feeble chemical effects. There is much importance in this suggestion, if I may trust to my own observations.

The same principles apply to *intercostal neuralgia*, and to the trophic form of this disease known as *herpes zoster*. (Fig. 84.) In treating these affections, the anode rests on the spine at the point of emergence of the nerve roots, and the cathode at the periphery about the median line of the body in front. It is good practice in these cases, also, to place the anode on the painful points, where the nerves become superficial, and the cathode on the terminals. The applications may be both labile and stabile. Neumann[2] reports a case rebellious to galvanism, cured by two *séances* of cutaneous faradization.

In no painful affection is the application of electricity more conspicuous for good than in *sciatica*. There is a general agreement amongst authorities as to the exceptional value of galvanism in this disease, and yet, several cases have been reported in which faradism was more effective. My own experience is decidedly in favor of a large number of cups in old cases, which I have seen yield in a surprising manner to the applications. The method advised by Onimus and Legros should be pursued. A large sponge-covered electrode—the anode—well moistened with warm water, without salt, is placed

[1] Traité d'Electricité médicale, p. 298 et seq.

[2] Gazette méd. de Paris, No. 7, 1878. Névralgie intercostale rebelle au courant continu, guérie en deux séances de faradisation cutanée.

over the nerve at its point of emergence from the pelvis; and the cathode, equally large, should be applied by the labile and stabile methods over the distribution of the nerve, special attention being given to the painful points. Forty to sixty elements should be used, and the applications made twice each day, if practicable, but always once a day. Benedict[1] proposes another mode of application, which he has found effective; he uses a bulbous electrode, which is introduced into the rectum, and directed to the position of the sciatic. Eulenburg[2] advises a current from twenty to thirty elements, and stabile applications, the sittings from five to ten minutes. Hammond succeeds in effecting cures in a very short period of time by employing electro-puncture, which consists in introducing a suitable needle insulated nearly to its point, and connecting it with one of the poles. A great many reports showing the utility of galvanism in sciatica have been published. Beside the special treatises, the reader may consult with advantage the papers of Knot,[3] Stephenson,[4] Seegen,[5] and Gibney.[6]

Lumbago is usually promptly cured by galvanization of the affected muscles. In my experience in this class of cases, strong currents are most beneficial; attacks resisting the current from fifteen to twenty cups of Siemens and Halske have promptly yielded to forty to sixty. The applications should be made twice a day for the first few days, and afterwards daily until a cure is

[1] Wiener med. Presse, Nos. 21 and 22, for 1872.

[2] Lehrbuch der funct. Nervenkrankheiten, etc., p. 169.

[3] Lancet (London), Dec. 18, 1875.

[4] Med. Press and Circular, Jan. 3, 1872.

[5] Wiener med. Presse, Nos. 34, 35, 37, and 38, for 1872.

[6] American Practitioner, March, 1879. "Galvanism in the Treatment of Sciatica." He reports fifteen cases treated by galvanism alone successfully.

effected. Immediate relief is afforded by the passage of a current, the patient being able to straighten himself at once without pain, but in the intervals he lapses back into his former condition nearly, but the repetition of the applications is followed by an increasing duration of the relief. Recent cases are more amenable to cure than old cases, and sometimes are cured by a single application. The best results are obtained by transverse currents, the electrodes, which should be large, being placed on each side. Both stabile and labile applications should be practised.

Myalgia in other situations is generally quickly relieved by electrical treatment applied in the same way as described for lumbago. The direction of the current has apparently but little influence, but in my experience transverse currents are more effective in muscular affections. The operator will do well, however, to pass the current through the muscles affected in both directions, and the anode on the spine, the cathode passed over the muscles by descending labile applications.

The pain, soreness, and muscular feebleness which persist for some time after an attack of *acute rheumatism*, are greatly relieved by galvanism, a descending labile current of moderate strength being most efficient. The effusions into the sheaths of tendons left by rheumatism, become absorbed under the stimulation of electricity. Great relief is afforded in chronic rheumatism by persistent galvanic treatment. Patient and painstaking applications may bring about absorption of inflammatory exudations around joints and in the sheaths of tendons. Meyer reports having caused the disappearance of nodosities about joints in chronic rheumatism by galvanization of the cervical sympathetic, and

Althaus[1] subsequently published similar experience. Such a result is explicable only on the theory that in this way stimulation of the trophic system was effected in such a degree as to excite absorption of the morbid deposits about the joints. This method, as well as central galvanization, may be conjoined to the local galvanic applications.

In their report on the results of electrical treatment, as administered in the wards of Prof. Schwanda, Drs. Gumplowiez and Klotzberg speak in strong terms of the value of electricity in rheumatismal affections. The most numerous and satisfactory of the cases falling under their care were the rheumatic affections of the muscles and joints. "With the greatest caution in estimating therapeutic facts," they say, "in view of the success, often truly surprising, which we have obtained, we may affirm with confidence, that electricity is a sovereign remedy in most rheumatic affections." In cases of muscular rheumatism with paresis of the affected muscles, they hold that an interrupted galvanic current should be used; in chronic articular rheumatism, cutaneous faradization is preferable.[2]

The various neuralgic affections situated in superficial nerves have been treated with success by faradic applications, by many electro-therapeutists, notably by Duchenne, and by Mitchell, Morehouse, and Keen. It is most serviceable when applied as follows: the skin is thoroughly dried, and then some drying powder is dusted over the surface to be acted on. A strong faradic current with excessively rapid interruptions is then applied along the trajectory of the nerve by means of the brush or metallic terminals.

[1] The British Medical Journal, Sept. 28, 1872.

[2] Wiener med. Presse, Nos. 14, 17, and 19, for 1874.

It may be desirable to supplement the foregoing observations, by some additional facts, of an explanatory kind. As regards the applications of faradic electricity, there are two modes followed. One method consists in the use of the secondary current with excessively rapid interruptions, the spinal origin and the peripheral expansion of the nerves being in turn acted on. The other plan consists in applying a dry metallic electrode, or a brush of fine wires, to the skin carefully dried. Excited in this way, the skin may be merely reddened, or burned so that the epidermis peals off. Two therapeutical effects are obtained from these faradic applications: one is the counter-irritant effect; the other is the more distant vaso-motor influence—for as Strumpf, and some other observers have shown, cutaneous faradization of one limb causes a rise of temperature in the other.

The galvanic current is also applied in two modes: by the polar method—one pole placed in the seat of disease, or on the tender points, and the other on some indifferent point; by the ordinary application of both poles, the positive, placed on the spine or over the nerve at its point of emergence, and the negative at the peripheral expansion. The applications may be stabile or labile. If labile, the positive pole is placed over the trunk of the nerve, and the negative is brushed over the whole peripheral distribution. Very recently Dr. Moritz Meyer[1] has published some very striking cases, illustrating the good results obtained from anodal application to "painful pressure-points." These painful points are discovered on pressure at various places; at the spine, at spots along the course of the nerve trunks, and the branches. To these points the anode is applied for

[1] Berliner klinische Wochenschrift, No. 31, 1881.

a few minutes. Success has been obtained by this method, when the usual galvanic applications failed.

By any of these modes of application, the so-called catalytic effects are obtained. The local galvanic treatment may also be effectively supplemented by central galvanization, by stimulation of the ganglia of the sympathetic, and by general faradization. All of these applications stimulate the vegetative functions, which are depressed to a greater or less extent, and they all promote nutrition.

Visceral Neuralgia.

Hemicrania, or *migraine* (sick headache), usually regarded as a neuralgia of the fifth, is a very different affection from tic douloureux, or simple neuralgia, and belongs rather to this division of the subject. It is closely associated with stomach disorders, for the reason, doubtless, that the nucleus of the fifth and the nucleus of the pneumogastric lie in close proximity, and are connected with commissural fibres. Treatment directed merely to the nerve will, therefore, usually fail, and equally unsuccessful will be the management which is confined to the stomach disturbance; both methods must therefore be conjoined. The ophthalmic division of the fifth, of either side, is the seat of the pain. The treatment by galvanism consists in applications to the fifth nerve—the anode on the supra-orbital nerve and the cathode on the mastoid. Stabile applications are preferable. Galvanization of the sympathetic is an important addition to the treatment of the nerve. Du Bois-Reymond, himself a sufferer, was the first to point out the vaso-motor and pupillary phenomena in these cases. The necessity for galvanic treatment of the pneumo-

gastric is not less obvious. The cervical sympathetic and the pneumogastric can be simultaneously galvanized by placing one electrode behind the angle of the jaw, and the other on the *manubrium sterni*, or on the epigastrium. The treatment during the paroxysms is at least merely palliative. During the interval between the seizures, beside a careful regulation of the diet and general hygiene of the patient, the irritability of the nervous apparatus should be removed by systematic daily applications of galvanism to the fifth, the sympathetic ganglia, and the pneumogastrics. An evident improvement in the body nutrition takes place, the attacks diminish in number and lessen in violence, and ultimately they cease to reappear in a considerable proportion of cases.

During these paroxysms, in those cases of hemicrania accompanied by flushing of the face, throbbing temporals, and increased action of the heart, relief may usually be afforded by a very mild faradic current confined to the skin of the painful region, and a stronger current to the cervical and dorsal spine. The interruptions must be as rapid as possible, and the current strong enough merely to produce a faint tingling when applied to the eyelids and forehead. The electric hand is a good method of application under these circumstances. The person of the operator charged, the fingers of the disengaged hand are slowly passed over the affected area, for a period of ten minutes.

Electricity is useful in all the forms of *angina pectoris*, but the best results are obtained from the applications when the cases are free from recognizable cardiac changes. In true angina pectoris, the effect of judicious treatment is to diminish the violence and lengthen the interval between the seizures. For obvious reasons,

the paroxyms cannot be subjected to treatment. In hysterical and simple neuralgic angina, the paroxysms may be treated and the pain relieved by applications of the faradic and galvanic currents, the former employed as a counter-irritant to the walls of the chest, and the latter applied to the pneumogastric and to the sympathetic, the positive pole behind the angle of the jaw and the negative over the præcordial and epigastric regions. Employing galvanism in the interval, Eulenburg[1] had very good results in several cases of the genuine malady, the paroxysms being rendered lighter and less frequent.

Gastralgia, *enteralgia*, *hepatalgia*, and other neuralgiæ of the nerve plexuses in the abdomen, are to a greater or less extent improved by galvanism when they assume a subacute or chronic form. When a constitutional condition underlies the local morbid state, attention must be directed to its relief. The strumous, syphilitic, paludal, or plumbic cachexia may be concerned, and, until special treatment is directed against it, relief cannot be obtained. The cure of the cachexia may finally dispose of the pain, but it is not unfrequently the case that the habit of pain once induced in the nerve persists after its cause has been removed. The various abdominal neuralgiæ are best treated by a rectal electrode, and a large sponge-covered electrode applied to the epigastrium, right and left hypochondrium, and the other regions in turn. It is probable that excellent results could be obtained from a properly insulated electrode for the stomach, in cases of gastralgia and of neuroses affecting the semilunar ganglion and solar plexus especially. Faradic electricity may be used also in these cases—a mild current and very rapid interruptions—for the anodyne effects, and a

[1] Lehrbuch der functionellen Nervenkrankheiten, loc. cit.

strong current to the skin only as a counter-irritant. In making applications for the relief of abdominal neuroses, it is good practice to include galvanization of the pneumogastrics and of the cervical sympathetics, and of the dorso-lumbar enlargement of the cord.

CHAPTER VII.

ELECTRICITY IN ANÆSTHESIA AND ANALGESIA.

Cutaneous anæsthesia and analgesia may be produced by various causes; by division of the nerve trunk innervating the part; by lesions of the cord or brain. It may also be an hysterical condition, and one of the protean forms of hysterical manifestations, as hemianæsthesia, or bilateral anæsthesia. It may occur as a sequel of typhoid or other acute affection, when it occupies a small area usually of an extremity. It is a frequent symptom in cases of syphiloma of the middle fossa of the skull, and involving the pons when it is bilateral, although not universal, but in patches. The sense of touch may be involved only, and the needle compasses felt as two when very far apart, or are not felt at all; in other words, the anæsthesia may be partial or complete. The sense of touch may be retained and the sense of pain abolished, or *vice versa*, or both may be wanting, thus indicating that the senses of touch and pain are separate endowments of the nervous system.

In the treatment of these affections physiological data may be applied with success. A descending galvanic current allays irritability, and an ascending current has

the opposite effect. In the electrotonic state, catalectrotonus is a condition of heightened irritability. As a rule, the faradic current, being more exciting, is more effective in treating these states. As the current is to be confined to the skin, the part requiring the treatment must be carefully dried, dusted with some drying powder, and the applications made by the electric brush or metal electrodes. When anæsthesia is accompanied by languid circulation, and a tendency to trophic degeneration, galvanism is more efficient. An ascending current interrupted (labile) is the form of current most useful under these circumstances. The stronger applications are required as a rule.

The most important of the anæsthetic affections are those involving the nerves of special sense. *Anosmia*, loss of the sense of smell, may be a state of merely functional depression of the olfactory nerve, but is more frequently the result of disease of the Schneiderian mucous membrane, or of some intracranial lesion. The functional condition only may be amenable to electrical treatment, but in my experience this has proved rebellious, and such is the testimony of other observers,[1] but Duchenne reports successes with faradization in those cases dependent on alterations of the mucous membrane.

There is abundant testimony as to the efficacy of electricity in anæsthesia of the retina—*amblyopia*, *hemeralopia*, *amaurosis*, *anæmia of the optic disk*, etc. Successful cases have been reported by Pye-Smith,[2] Fraser[3] (Donald), Benedict,[4] Arcolo,[5] Seely,[6] and others. A form

[1] Althaus, p. 534. Op. cit.
[2] The British Medical Journal, May 18, 1872, p. 54.
[3] The Glasgow Medical Journal, Feb. 1872, p. 163.
[4] Allg. Wien. med. Zeit., Nos. 41, 43, and 44, for 1872.
[5] Arcolo: abstracted in Virchow und Hirsch's Jahresbericht, 1873.
[6] Archives of Electrology and Neurology, Nov. 1874, p. 213.

of functional depression of the optic nerve now very common is the *tobacco amaurosis.* Electricity affords prompt relief in these cases if the habit is relinquished. A similar condition is induced by sexual excesses, and other causes of functional depression. Whenever anæmia exists, galvanism ought to be employed; on the other hand, when hyperæmia is present, faradism. As anæmia is much the more common, galvanism is more useful. Applications can be made directly to the eyes. The anode, well moistened, should rest on the closed lids, and the cathode on the malar bone or temple. The strength of current should not be greater than sufficient to cause faint flashes of light, and the *séances* not longer than two or three minutes. Besides the direct applications to the eye, this organ can be acted on indirectly through the cervical sympathetic, to which treatment should also be directed. When faradism is employed, the current should be rapidly interrupted, and not stronger than can be readily borne. The extra current is well adapted to the treatment of these cases. The use of faradic and interrupted galvanic applications, in the treatment of muscular troubles of the eyes, has been discussed in a previous chapter.

Anæsthesia of the auditory nerves has received a new and admirable interpretation by the investigations of Brenner. Stimulation of the nerve by the galvanic current produces certain reactions or sounds. The ear is filled with warm water, with which the electrode communicates, or a special electrode is employed, the ear, also, containing as much water as it will hold. Immediately on closing the circuit with the cathode (CC), a noise is heard, and it lessens as the closing proceeds. Cathodal opening (CO) produces no reaction, or at least causes no sounds. Anodal closing (AC) has no effect, but at

the anodal opening (AO), if a current of sufficient strength is used, a sound is heard. The method of Brenner, or the "polar method," has been the subject of much discussion, but the opposition to Brenner's results has much declined, since his views have received the powerful support of Erb, and other influential electrologists. Wreden,[1] who has worked in conjunction with Brenner, Weber,[2] and Neftel,[3] have also had good results from the polar method. Although I have not often succeeded in obtaining the reactions from the auditory, described by Brenner, I have had good effects from galvanism, in dulness of hearing, noises in the ears, inflammatory thickening of the drum, etc. Rumbold,[4] Itard,[5] and others have stopped *tinnitus aurium*, after it had in some cases existed for years. It is impossible beforehand to designate with accuracy the cases of dull hearing which will be improved by electrical treatment, except by exclusion, separating those in which the impaired audition is a result of incurable disease of the auditory canal, the drum, and the middle ear. Persevering treatment may be necessary even in favorable cases. On the other hand, very marked improvement has been caused by a single application, or by a few applications.

[1] Virchow und Hirsch's Jahresbericht, vol. vi., 1871.

[2] Ibidem, vol. vi., 1871.

[3] Galvanotherapeutics, op. cit.

[4] Archives of Electrology and Neurology, 1874.

[5] Thése de Paris, 1874.

CHAPTER VIII.

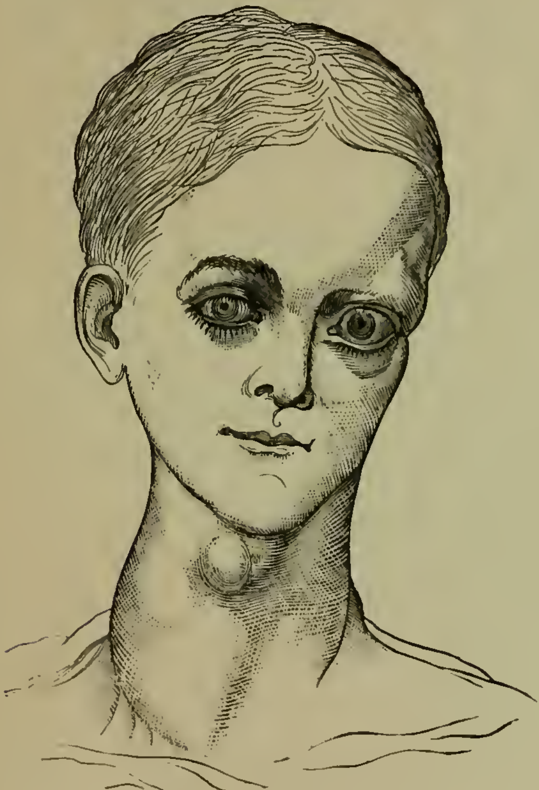
ELECTRICITY IN THE VASO-MOTOR AND TROPHIC NEUROSES.

The vaso-motor and the trophic system are not necessarily the same. The functions of the former may be very much disturbed, without any alteration in the nutrition of parts. On the other hand, lesions of certain nerves are followed by trophic alterations in the parts to which they are distributed: injuries to the ophthalmic division of the fifth are followed by destructive ulceration of the cornea, inflammation of the conjunctiva, etc. When the multipolar ganglion cells of the anterior cornua of the spinal cord are diseased, there ensues rapid wasting of the paralyzed parts. These facts rather indicate the existence of a special trophic system. Nevertheless we may conveniently study in one chapter the action of electricity on both.

Exophthalmic goitre is the type of an affection of the vaso-motor system, when it is free from structural changes in the heart and great vessels. The normal inhibition of the cardiac movements is lowered and the vascular tonus is equally debased, the effect of both being to increase the rate of pulsation. The action of the heart is rapid and bounding, and the radials, the carotids, and the vessels of the thyroid gland beat vehemently. The disturbance in the functions of the sympathetic system needs to be the only pathological condition present, but in cases of long standing and in old subjects, various changes take place in the heart, the aorta, the thyroid gland, and in the tunics of the vessels

generally. (Fig. 85.) Recent cases treated efficiently by galvanism are relieved permanently, or the course and progress much modified. During exacerbations, which constitute a prominent feature of the clinical his-

FIG. 85.



Exophthalmic goitre.

tory, the passage of a sufficient galvanic current through the pneumogastric immediately lessens the cardiac excitement. In the treatment for curative results, a mild current is held to be most efficient (Chvostek). An electrode—the anode—is placed in the angle behind the jaw, and the cathode on the epigastrium, and a stabile

current is allowed to flow for three to five minutes. The cervical spine should also be galvanized. It may be included in the circuit by placing the anode over the vertebra in turn, whilst the cathode rests on the epigastrium. Stabile may be varied by labile applications. The faradic current may also be used successfully, an instance of this having come under my notice. The first published cases illustrating the curative value of galvanism, were those of Chvostek,[1] who followed with a new series of examples the next year,[2] when Meyer[3] also reported several cases. In 1874, I read a paper before the medical section of the American Medical Association, advocating this plan of treatment, and illustrated its advantages by the details of five cases. In 1878, Vizioli,[4] in a paper on electrotherapy, amongst other cases, narrated several of Basedow's disease, cured. In making the claim for the curative power of electricity, the reader should understand that uncomplicated cases only are referred to.

Very brilliant results have been obtained from galvanism in the treatment of trophic affections of the skin. I first employed galvanism for the cure of *acne* (acne vulgaris) with success; the whole integument of the face being stimulated by the electrodes. The direction of the current seems to be unimportant. From five to ten elements are necessary. One electrode may be placed in front of the ear, and the other passed over the eruption. The immediate effect is to irritate the skin and

[1] Wiener med. Presse, Nos. 41, 42, 44, 45, 46, 51, and 52, for 1871.

[2] Ibid., Nos. 23, 27, 32, 39, 41, 43, 44, 45, and 46, 1872.

[3] Berliner klinische Wochenschrift, No. 39, 1872.

[4] Elettroterapie practica. Morgagni, Gennajo, p. 69, 1878. Quoted and abstracted by Virchow u. Hirsch, Jahresbericht, 1878. Eulenburg, also, speaks favorably of the good effects of galvanism. Ziemssen's Cyclopædia, vol. xiv.

flush the face, but these symptoms quickly subside, leaving the face pale and the eruption less prominent. A cure can usually be effected by persevering treatment in the worst cases. Some attention to diet is also necessary in these cases, and as the eruption appears at the period of puberty, correction of menstrual irregularities may be required, and of moral irregularities on the part of boys. Dr. G. M. Beard called attention, in 1872,[1] to the treatment of affections of the skin, presumably of neurotic origin. He employs central and peripheral galvanization and general electrization, as he has defined and illustrated these modes of treatment. The affections in which he employed electrical treatment with success were, *eczema*, *psoriasis*, and *prurigo*. Dr. G. W. Murdock[2] reports a case of *eczema capitis* cured in six weeks of electrical treatment after it had existed nine months. Dr. Piffard,[3] of New York, the author of a valuable work on skin diseases, and inventor of a beautiful galvano-caustic battery, has published an essay on the value of electricity in the treatment of skin diseases. More recently Armaingaud[4] has reported the cure of *scleroderma* by galvanism, an electrode—the anode—being placed on the spine, and the cathode applied to the diseased surface. He employed from twelve to twenty-seven elements. Not less remarkable are the results obtained in the treatment of ulcerations of the skin. The healing of *bed-sores* by galvanic couplets has been long known. A most interesting case, as showing the curative power of electricity, has been published by Dr. Deering.[5] Ex-

[1] American Journal of Syphilography and Dermatology, Jan. 1872, p. 12.

[2] Archives of Electrology and Neurology, vol. ii. p. 26, May, 1875.

[3] New York Medical Record, March 11, 1876.

[4] L'Union Médicale, 132, 1878.

[5] Galvanism in Strumous Ulceration. The American Journal of the Medical Sciences, April, 1873.

tensive and numerous *ulcers* of a limb, succeeding to "milk-leg," were cured by galvanic treatment, in which the anode was placed on the spine, and the cathode on the foot, the whole limb being included in the circuit. Not less remarkable are the results obtained by Glax[1] in the treatment of *œdema* (general) and *ascites* by faradism. His method consists in procuring active muscular contractions by applying one electrode to the motor point and the other on the belly of the muscle (indirect electrization). Absorption, according to Glax, takes place when the muscles are made to contract sufficiently. The maladies in which this practice has succeeded are œdema from mitral insufficiency, œdema from emphysema and mitral insufficiency, and œdema from tricuspid disease. He claims to have succeeded, also, in cases of ascites from hepatic disease.

CHAPTER IX.

ELECTRICITY IN CONSTITUTIONAL DISEASES.

In cerebral, spinal, and peripheral nervous affections of *syphilitic origin*, I cannot speak too strongly of the good effects of electricity in restoring functional activity after preliminary mercurial or iodine treatment has removed the specific lesions. There is a period in the course of these affections when, after an arrest of the morbid process, and absorption of the exudations, an inaction of the affected tissue persists. Galvanic and sometimes faradic applications will, under such circum-

[1] Deutsches Archiv für klin. Medicin, vol. xxii. p. 611–618, for 1878.

stances, raise the tonus of the vessels and excite the depressed functions to renewed activity. In *syphilitic paraplegia* especially have I seen good results from combined spinal and nerve-trunk applications. The presence or absence of the reactions of degeneration will depend on the seat and character of the lesions, and the current employed will necessarily be determined by the character of the reactions. The methods employed will be the same, of course, as for the non-specific diseases of the same tissue and organs. Great relief is afforded to the pain of *nodes*, and absorption promoted by galvanism. In the neuralgia of the so-called *tertiary disease*, as it occurs in old subjects who have been saturated in turn by mercury and iodine, and are much broken in health, it constitutes a most precious resource. In such cases central galvanization should be practised as well as the applications to the affected nerves.

Remak[1] long ago insisted on the value of electricity in the treatment of *chronic rheumatism*. To explain the results he utilized his convenient phrase—*catalytic effects*. I have already alluded to the relief to pain, and the absorption of effusions into and about joints, which take place under the galvanic applications. Similar relief is afforded in *gout*, after the acute symptoms have subsided somewhat: the pain is relieved, and the swelling removed. Faradism has also been used with success in rheumatism, by Betz[2] and Abramovski.[3]

In the *rheumatic* and *neuralgic affections caused by the poison of lead*, very prompt relief is afforded by galvanism; but remedies to procure elimination of the mineral

[1] Galvanothérapie—French edition, translated by Dr. A. Morpain. Paris, 1860, p. 232 et seq.

[2] Archiv für klin. Med., xviii. 482–495.

[3] Berliner klin. Woch., 7 and 8, 1876.

are not the less necessary. The method to be pursued in the application of galvanism is the same as in the idiopathic forms of these maladies.

In the neuralgic troubles of the paludal cachexia, temporary relief is afforded by galvanism; but, as other available measures are effective in bringing about a cure, it is the less necessary to employ a mere palliative.

As a means of improving the nutrition of the body in general when low from torpor of the assimilative functions, galvanism is efficient. Central galvanization, and the usual application to the cervical sympathetic and pneumogastrics, stimulate the nerves supplying the chylopoietic viscera, and thus increase the activity of these organs. The body-weight usually gains under these modes of applying the current. Messrs. Beard and Rockwell[1] have introduced another plan, entitled "general electrization," the object of which is to energize the various functions of the organism, and to improve the nutrition. The following is the method of making the applications: the feet are placed on a copper plate, one electrode; the other electrode is passed successively over every part of the body, from the head downwards; and a faradic current just strong enough to cause moderate tingling is used. Daily *séances* of fifteen minutes to a half hour are practised. Beard says, rather *naïvely*, that this method does not involve any exposure, as a blanket of sufficient size may be fastened about the throat, and under this the operator can manipulate the electrode.

Weir Mitchell[2] proposes another method for improving the nutrition in nervous subjects, composed of mas-

[1] Medical and Surgical Electricity, 3d ed. Wm. Wood & Co., New York.

[2] Fat and Blood, and How to Make Them.

sage, inunction of fat, and faradization. As these patients are not permitted to make any voluntary efforts, faradization effects that amount and degree of muscular action necessary. All of the muscles accessible are in turn made to contract by a faradic current every day. A distinct rise of temperature is observable, when the muscles have been thus made to act, a fact in harmony with those physiological observations which have demonstrated that the principal source of heat-production in the body is in the muscular tissue. By the Mitchell method, of which muscular faradization is an important part, a rapid gain in body-weight takes place.

CHAPTER X.

ELECTRICITY IN LOCAL, OTHER THAN NERVOUS DISEASES.

THE electrical treatment of nasal and pharyngeal catarrh has been relegated almost entirely to irregular practitioners — so-called electricians — who find in this malady a fine field for the exercise of their arts. Independently of experience, the results of which justify me in advocating the electrical treatment of this affection, there are facts which seem to indicate the utility of faradism and galvanism. The influence of galvanism over the circulation, applied at any point, and of faradism, when the current can act on the vaso-motor system directly, are now well-established facts. That galvanism will cause the absorption of effusions and effect the healing of bed-sores and ulcers, is equally true. The pathological changes in naso-pharyngeal catarrh including these processes, it would not seem doubtful that

electricity must be serviceable. In my experience these theoretical considerations are amply justified by the success of the practice.

In the electrical treatment of naso-pharyngeal catarrh, certain procedures seem best adapted to bring about good results. If there be vivid redness of the mucous membrane, swelling, and muco-purulent discharge without solution of continuity, faradic applications are most effective. If ulcerations exist and the surface of the mucous membrane is studded with enlarged follicles, more or less atrophic degeneration of the membrane having taking place, galvanism produces better results. Before applying the electrodes, the passage should be cleaned by injecting with the post-nasal syringe a solution of common salt, or of ammonium chloride. The intra-nasal electrodes should be insulated nearly to the extremity, which should have a flattened bulbous or olive shape, and should be flexible. The other electrode, of small size and button shape, may be covered with soft leather. The intra-nasal electrode, well warmed, connected with the negative pole, should be passed along the floor of the nostril until the posterior extremity of the canal is reached, where it may rest during the application. The external positive electrode should be passed over the nose, resting over the ethmoidal sinus, the root and body of the nose, and on the cheeks. Strong currents are not admissible, only so strong that faint flashes of light are produced. The negative electrode is preferred for the intra-nasal application, because of its more decided chemical and catalytic effects. When faradism is employed, it is indifferent which electrode is applied internally or externally. Persistence in the treatment of the chronic cases is very necessary, but if carried on faithfully a sufficient time, good results may

be expected. In pharyngeal affections, a curved bulbous electrode can be introduced and applied to all parts. The current must be weak lest nausea and vomiting result.

Vomiting, catarrh of the stomach with dilatation, and atonic dyspepsia, have been treated successfully with galvanism by Lente,[1] Neftel,[2] and others. The form of vomiting relieved by galvanism is the nervous, in which no affection of the mucous membrane and no indigestion are supposed to exist. Descending stabile applications to the vagi and sympathetic, and central spinal applications are the most efficient. A mild current only should be employed. The anode should rest in the usual position in the fossa behind the angle of the jaw, and the cathode on the epigastrium, for the one form of applications; for the other, the cathode should as before be placed on the epigastrium, and the anode on the spine, descending to a point about opposite the former. The central spinal galvanization to be effective requires a much stronger current, twenty to thirty elements being necessary.

A great many observations have been reported, proving the efficacy of electricity in *constipation* and *impaction of the bowels.* Thus Basch[3] gives an account of a severe case of constipation occurring in an anæmic subject, relieved promptly. I have treated a number of cases of habitual constipation with success, but the permanence of the results depends on the adherence of the patient to a necessary regimen afterward. In impaction of the bowel, electricity is highly successful. Cases of obstruction due to this cause, cured by galvanism or

[1] Archives of Electrology and Neurology, i. p. 193.

[2] Centralblatt, f. d. med. Wiss., No. 21, 1877.

[3] Wiener med. Blätter, No. 12, 1878.

faradism, have been published by Curci,[1] Wharton,[2] Mancini,[3] Santopadre,[4] Mario,[5] Dutenil,[6] etc. The mode of action, and the limitations of usefulness of the current in these cases are obvious. Contractions are excited in the muscular layer, previously in a paretic state, and the contents of the canal dislodged. This practice is eminently proper and judicious before any inflammatory reaction has taken place, but is improper if local tenderness and the constitutional state indicate the development of inflammation. In the more serious condition —invagination — faradic electricity has effected cures. Bucquoy[7] has given an account of three cases thus cured, Mario has narrated others, and Ballouhey[8] has collected twenty-two cases of occlusion from various causes cured by the application of an interrupted galvanic or of a faradic current. The mechanism consists in the forcible contraction of that part of the canal reached by the current, and the consequent traction exerted on the invaginated portion of the bowel. When a galvanic current is employed to release the imprisoned bowel, the action is probably different: from the point where the electrode is applied, a peristaltic movement is started, and this must accomplish the result by acting on the invaginated portion. One electrode is placed in the rectum, and the other is passed over all parts of the abdomen in turn, the direction of the current not being important.

[1] Quoted in Virchow-Hirsch for 1877.
[2] Phila. Med. Times, April 1, 1876.
[3] Quoted in Virchow-Hirsch for 1876.
[4] Ibid. [5] Ibid. for 1875.
[6] Bull. Gén. de Thérap., 30 Juillet, 1872.
[7] Journ. de Thérapeutique, Nos. 4 and 5 for 1878.
[8] Thése de Paris, 1880.

Faradism and galvanism occupy an important place in the treatment of depressed states of the *respiratory* and *cardiac functions*. The chief danger in *opium narcosis* is the suspension of the respiration; by faradism this danger is overcome. Furthermore, faradism may be usefully applied as a means of irritation instead of flagellation, and is both more effective and more seemly. Indeed, faradism has become so useful in the treatment of opium narcosis, that few cases are treated without its aid. The proper mode of conducting the applications, is to apply one electrode to the spine and the other along the attachment of the diaphragm. A current of sufficient intensity should be transmitted rhythmically, to induce action in the normal time and order. Beside the muscular contraction, the irritation of the current excites voluntary breathing by a reflex impression on the respiratory centre. The same principles and methods apply in the case of poisoning by *chloral*, *gelsemium*, *conium*, *curara*, and the respiratory poisons in general. When dangerous symptoms arise from respiratory failure in cases of ether inhalation, faradism is also indicated. When the source of danger from poisons and from chloroform inhalation is failure of the heart, much less is accomplished by electricity. Indeed, mischief is often done by the untimely use of strong currents. Electro-puncture has been tried, and one case is reported of chloroform narcosis in which the heart, already arrested, was made to contract again by this expedient. According to this method, a fine needle properly insulated is introduced into the substance of the heart (left ventricle) a short distance, and the other is placed on the parietes of the chest. Such a measure is proper only when less dangerous methods are unavailing.

The utility of electricity in the treatment of certain

uterine disorders is very decided. Tripier[1] in France, and myself[2] in this country were amongst the first to advocate galvanic treatment in nutrient diseases of the uterus. In cases of sub-involution, congestion without connective-tissue hyperplasia, and in chronic metritis, both faradic and interrupted galvanic applications are highly serviceable—the former because the current can be made to act directly on the vessels of the part. In cases of *menorrhagia* occurring in nervous subjects, I have had admirable results from galvanization of the dorsal and lumbar spine. In these cases of increased blood supply to the womb, the organ can be best treated in married women, by direct applications—a suitable electrode insulated to near its extremity, being placed in contact with the womb, and the other on the hypogastrium or on the lumbar spine. Remarkable results have been obtained in cases of *uterine inertia*, *post-partum hemorrhage*, and *retained placenta*. One electrode of the faradic battery is introduced far enough to come in contact with the womb, and the other is placed on the hypogastrium. The current should be strong enough to excite firm contractions, which it will hardly fail to do. This is a more certain and scientific expedient and, also, a greatly more expeditious one than the use of ergot. The expulsion of polypi, of moles, and of hydatids has been quickly effected by faradic applications. The cases adapted to this treatment are those in which the polypus lies in the distended cervical canal, those beginning to protrude held by the pedicle, and those yet in the uterine cavity, but efforts at expulsion having begun. Displacements of the uterus have been reported cured by electricity, but in these cases it is probable that the

[1] Archives of Electrology and Neurology, vol. i. pp. 146–158.
[2] Phila. Medical Times, vol. i.

displacement spontaneously yielded on the removal of its cause. Many cases of retroversion result from sub-involution, formation of fibroids, and the pressure of neighboring organs. The first and second of these causes may be made to disappear by galvanism, and then the abnormal position may be rectified. Facts have been reported by Mann,[1] Zarmini,[2] and others. That chronic metritis and the development of fibroid tumors can be arrested, seems probable, but certainly the facts do not warrant the assertion, that these affections can be readily cured. Patience and perseverance in the applications will doubtless be ultimately rewarded by improvement, sometimes by cure. Much of the pain and discomfort caused by a growing fibroid may be relieved by galvanism. Whilst faradism is preferable in cases requiring the muscular action of the uterus, galvanism is preferable when nutritive changes have taken place.

Amenorrhœa has been relieved by faradism, galvanism, and static electricity. The last has been referred to. The form of amenorrhœa adapted to this treatment is that dependent on torpor of the organs. The most effective plan of making the applications consists in placing an electrode in or against the *os uteri*, and the other on the spine or hypogastrium, but in virgins both poles should be external. Amenorrhœa has, also, been effectively treated by Sir James Simpson's intra-uterine galvanic stem, but this procedure is not free from danger. Before undertaking the treatment of amenorrhœa, the practitioner should assure himself of the non-existence of pregnancy.

Electricity is used with varying success in certain dis-

[1] New York Medical Record, April 15, 1873.

[2] Quoted by Virchow u. Hirsch's Jahresbericht, vol. i., 1874.

eases of the male genito-urinary organs. In general, it may be affirmed that the results are not so good as in the corresponding maladies of the female organs. The difference is due, most probably, to the greater simplicity in structure and accessibility of the latter. *Irritability of the bladder* may sometimes be relieved by a weak galvanic current—one electrode resting on the spine; the other on the perineum and hypogastrium. A more direct application of galvanism is effected by the introduction of an insulated sound—the extremity of metal and olive shaped—carrying it far enough to rest in the prostatic urethra. This method may be especially serviceable when the irritability of the bladder accompanies chronic hypertrophy of the prostate. Under these circumstances strong currents are injurious; from five to ten elements—often less than five—should be used. The frequent introduction of the sound is irritating, also, and by means of it germs of fermentation are introduced into the bladder. Having had considerable experience in the management of these cases, I am prepared to admit that the *summum* of benefit is nearly in many cases overcome by the disadvantages named, although it is undeniable that in other cases much relief is afforded. In some of the forms of *impotence* both galvanism and faradism may prove curative. In the functional impotence which succeeds to excesses, abstinence and faradization of the external genitals will not unfrequently speedily effect a cure. In these cases a marked degree of anæsthesia may exist on one side of the penis, over one testicle, or parts of both sides may be thus affected. The electric brush may be used to these anæsthetic spots with advantage. An interrupted galvanic current may be highly useful—a suitable urethral electrode resting in the membranous urethra, and the other pole passing

over the external genitals. A very frequent condition, the importance of which these unfortunate subjects greatly exaggerate, is the following: frequent nocturnal losses; escape of seminal and prostatic fluid on the least venereal excitement; imperfect erections; ejaculation on the least contact. The despondency, mental preoccupation, and the feelings of moral wretchedness, which accompany this condition of the sexual organs, allow

FIG. 86.

Genital irritation in a child.

scarcely any other feeling or thoughts to occupy the mind, and hence the impaired memory, the failing attention, etc., on which they lay so much stress. The relaxed state of the ejaculatory apparatus, or the vesiculæ seminales, and of the prostatic urethra, together with inadequate filling of the veins of the erectile tissue, and probably too rapid emptying of these veins by the dorsal vein of the penis, are the pathological conditions requiring correction. The mucous membrane of the prostatic urethra is also usually in an irritable and congested state. The positive electrode—a urethral sound insulated to within one inch of its extremity—should rest in this part of the canal, and the negative be passed over the external organs, spine, and perineum—labile descending method. If the negative electrode is kept in contact with the mucous membrane, it adheres tenaciously

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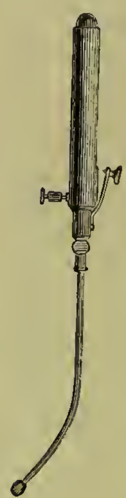
by reason of the electrolytic action. Faradic applications should also be made to the external parts by the brush at each *séance*. It is probable that the mental impression is an important factor in the curative results; on the other hand, these subjects, striving for an unattainable ideal, are constantly disappointed and fall out with every means of relief proposed.

The treatment of urethral stricture, hydrocele, varicocele, etc., pertain to the department of electrolysis, to which the reader is referred.

FIG. 87.

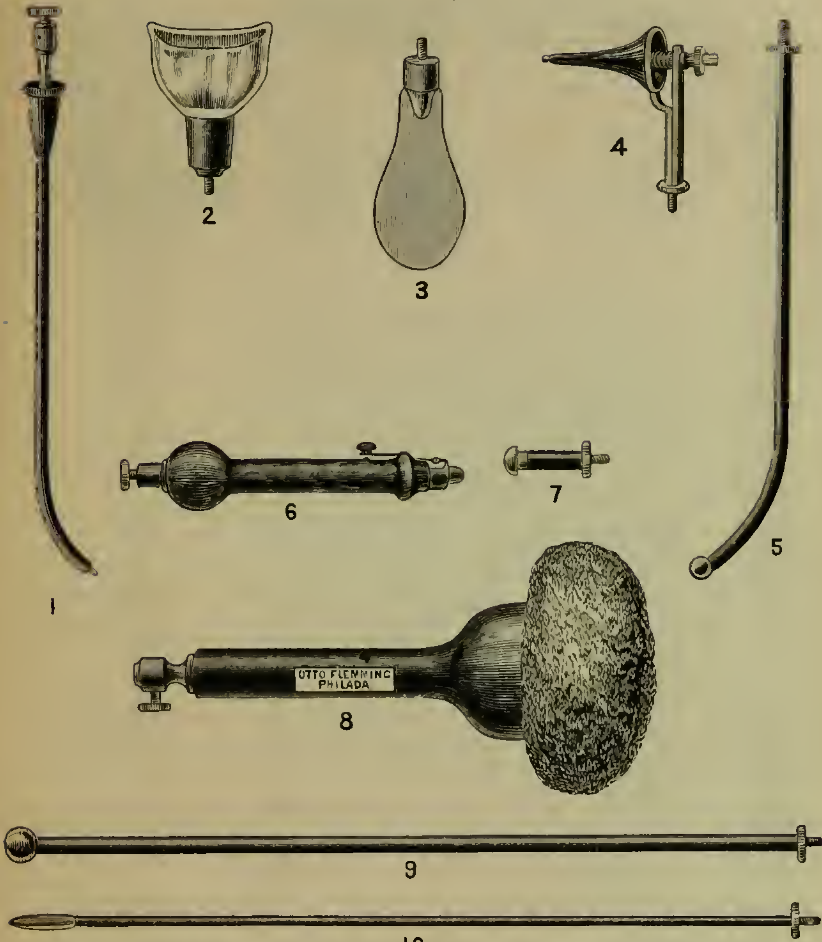


Interrupting handle.

FIG. 88.

Dr. Makenzie's laryngeal electrode.

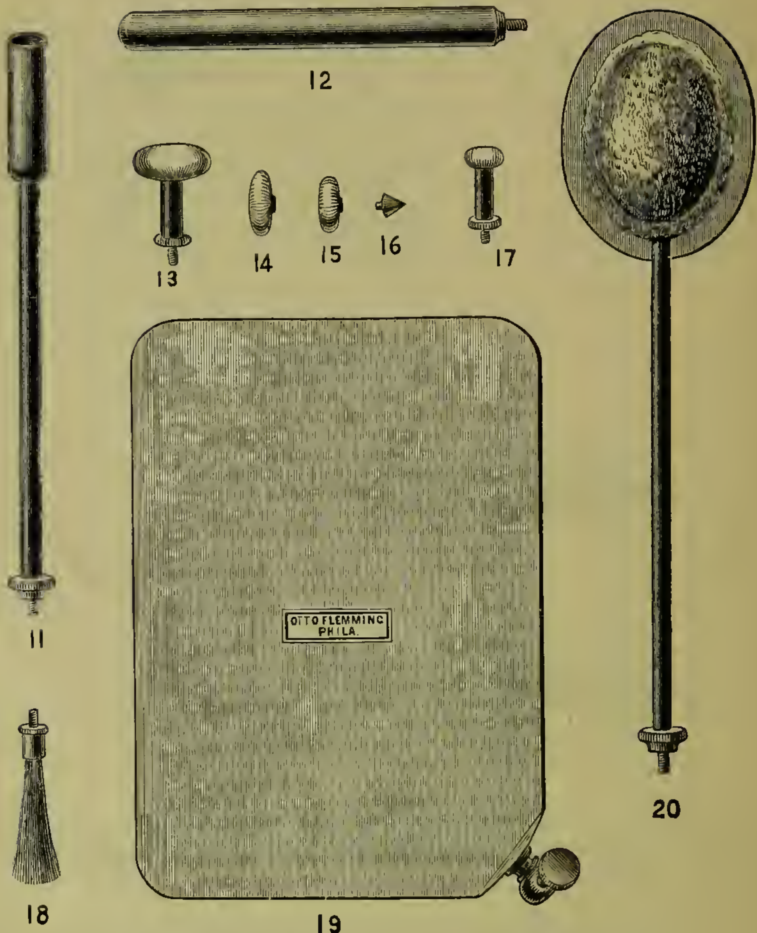
FIG. 89.



Forms of electrodes used in the various kinds of electrical applications.

1. Laryngeal (Dr. Strawbridge's Eustachian tube) electrode.
2. Eye electrode.
3. Tongue "
4. Ear "
5. Nasal "
6. Interrupting handle.
7. For special nerves.
8. Large sponge electrode.
9. Uterine and rectal electrode.
10. Urethral electrode.

FIG. 89 *a*.



11. Cup-shaped for mouth of womb.
12. Vaginal electrode.
13. Sympathetic nerve electrode.
14, 15, 16. Disks, olives, points, etc.
17. Carbon electrode.
18. Wire-brush "
19. Foot-plate "
20. Spinal "

PART V.

ELECTRICITY IN SURGERY.

CHAPTER I.

ELECTROLYSIS.

As animal tissues are composed of substances amenable to electrolytic decomposition, it is obvious that they must yield up their component elements, in accordance with the laws of electrolysis. Albumen is coagulated, salts are separated into acids and bases, and water is resolved into oxygen and hydrogen. When the salts contained in the animal tissues—soda, potassa, and lime—and water, are decomposed, the acid and oxygen appear at the positive pole, and the alkalies and hydrogen at the negative. It follows that if the positive electrode be composed of metal, it will be corroded by the action of chlorine and the acids, and the negative will remain unacted on and smooth. The tissues in the vicinity of each electrode are necessarily affected by the elements brought to them in accordance with chemical laws. About the positive, the mineral acids and chlorine form combinations, and hence do not attack the tissues with the same energy as those about the negative pole. If, however, the positive electrode is composed of zinc, for example, the chlorine attacking it will form chloride of zinc, a very corrosive material. This principle has been utilized to produce caustic effects at the positive

pole. Although the negative electrode remains smooth, much more than at the positive, are seen there destructive effects from the action of the free alkali liberated in its neighborhood. When an ordinary carbon electrode covered with soft sponge is made to conduct a strong galvanic current, the skin speedily becomes reddened, and may be made to ulcerate, if the contact is sufficiently prolonged. If the carbon is applied directly, an intense burning is produced, and the tissues are destroyed, leaving a slough which is slowly detached, and the ulcer remaining is difficult to heal. The caustic action is due chiefly to the soda, potash, and lime. Some effect must, also, be allowed to the disassociation of the tissues, to their transference from point to point, and at the negative pole to the mechanical action of the liberated hydrogen.

For the purpose of electrolysis, the battery should have sufficient intensity. The zinc-carbon combination of Stöhrer, for portable use, is well adapted for electrolysis, the number of elements used not more than twenty, as the electro-motive force required will not exceed the power of this combination. It is held by some of the most experienced operators (Anderson,[1] Duncan,[2] Althaus[3]) that heating power must, also, be regarded, and hence the larger cells of Stöhrer are recommended, but this statement cannot be accepted without qualification. Smee's elements may, also, be employed for electrolysis, but Daniell's, Siemens' and Halske's, Hill's, etc., are not adapted for this purpose.

The battery employed by Robin[4] is the Gaiffe, which is

[1] The British Medical Journal, vol. ii., 1875, p. 518.

[2] Ibid., vol. i., 1876, p. 619.

[3] Medical Electricity, op. cit.

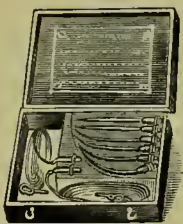
[4] De l'Électro-puncture dans la Cure des Anéurysmes intrathoraciques, etc. Thése de Paris, 1880.

composed of zinc and carbon elements, excited by chromate of potash solution. He advises from 40 to 60 cups, united to a pole-board with a suitable selector, so that additions can be made to the strength of the current without shock. Robin finds, as a result of his investigations, that the battery-current for this purpose should have an intensity of 45 milliwebers (milliampéres). This current strength is about equivalent to that obtained from 30 Stöhrer cells. As there is so much difference of opinion as to the number of cells required, the current strength should be exactly determined by an absolute galvanometer or by a suitable voltameter. Robin employs the galvanometer of Gaiffe, which has been reduced to the standard and graduated in milliwebers. Ciniselli has employed the voltameter. Robin finds that the current intensity of 45 milliwebers is equivalent to that which disengages a cubic centimetre of mixed gases in two minutes in the voltameter. Any of the elements mentioned above may, therefore, be used in electrolysis if their performance is ascertained by a standard galvanometer. In the absence of these scientific appliances, an operator is not helpless. The current strength may be ascertained in a practical way, by testing the needles in some white of egg. Robin finds that a current strength of 45 milliwebers is sufficient to cause coagulation of the albumen in twenty to thirty minutes. This, then, becomes a practical test of ready application under all circumstances.

Some electrolytic separation takes place, when the ordinary gas-carbon or brass electrode covered with sponge or soft leather is applied; but for electrolytic purposes, a special arrangement is necessary. As the morbid material to be acted on lies often to a considerable depth beneath the skin, a needle is necessary, and

as the sound tissues must be saved from damage, the needle should be insulated to within a half inch of its extremity (Fig. 91). The length of the needle will vary with the purpose to which it is applied, but usually they are from two to four inches in length. The smaller the better, consistent with the necessary strength. Ciniselli, Anderson, Dujardin-Beaumetz, and Robin strongly insist on this point. The diameter may be stated as between one-twelfth and one-sixteenth of an inch—or smaller or larger than this, as may be most suitable under the special circumstances. If too small, the needle may be destroyed by electrolytic action, or break as it is being introduced. To prevent oxidation, the uncoated part should be gilded. The insulation is extremely important; if defective, the current is deflected, the sound textures are burned, and hence the electrolytic action is inefficient. Various kinds of coating are recommended to secure proper insulation. Shellac, hard rubber, vulcanite, etc., are used. Hamilton[1] advises the following, which he has tested in actual use. As it seems to the author a good preparation, it is given for the benefit of those who may be unable to obtain the needles prepared by a competent dealer.

FIG. 91.



A box of needle electrodes.

Gum shellac (brown) one drachm.
Squibb's solution of India-rubber, one and a half drachms.
Wood naphtha, two drachms.
Mix.

With this solution, the needle is coated by successive additions of a thin layer, each one permitted to dry

[1] Clinical Electro-therapeutics, New York, D. Appleton & Co., 1875, p. 140.

thoroughly before the next one is put on. When sufficient coating has been laid on, it is rubbed down by the finest emery paper, and a final layer or two is then added to impart the necessary smoothness. The cutting end of the needle should be lancet-shaped, or triangular, to facilitate transfixing the skin, for a merely sharp needle will pass through the skin with difficulty. Each needle should have a short flexible insulated wire attached for convenience of manipulation, and four to six needles should be fastened to a handle arranged as the ordinary electrode handle, for adjustment to the poles of the battery. Dealers in medical electrical apparatus now furnish these needles, ready for application.

Aneurism.

The Operative Procedure.—There are important differences of opinion, and, also, of practice, in regard to the details of electrolysis as applied to the treatment of aneurism. The kind of elements and accessories, and the structure of the needles have been described. It is necessary now to determine the pole to be inserted, the time to be occupied in the process, and the management during and subsequent to the operation. Both poles induce coagulation. The clot formed at the positive is comparatively smaller, firmer, and more closely attached, whilst that at the negative pole is larger, softer, and looser in its attachment to the parietes. The needles are differently affected—the positive being rough, oxidized, and attached, the negative smooth, untouched, and readily withdrawn. Ciniselli, who has had a large measure of success and abundant experience, inserts the poles in alternation. Robin introduces the positive pole within the sac only, whilst the negative is placed at

some indifferent point on the integument. The reasons assigned by Robin for preferring the positive pole to induce coagulation, are the following:

The clot about the positive is firmer and more strongly adherent; the accumulation of hydrogen in the clot about the negative pole tends to disassociate the coagulum, and the gas, also, distends the aneurismal parietes, and local inflammation, suppuration, and sphacelus are more apt to occur about the negative than the positive. These reasons appear to us to be conclusive. There is, however, one objection to the positive electrode. The needle is so firmly imbedded in the clot and in the walls of the sac, that it is difficult to withdraw without disengaging clots or causing hemorrhage. The positive needle must, therefore, be withdrawn with great care. Robin recommends an instrument for this purpose; but by careful lateral pressure, and a delicate rotary motion of the needle, it can be withdrawn without accident.

The number of needles inserted into the aneurismal sac will depend on its size. From one to four needles are inserted in the most prominent part of the tumor, and about an inch and a half in depth, so that the movement of the blood current will impart to them a beat synchronous with the cardiac systole. The positive pole is connected with each needle in turn, and the current transmitted begins at the minimum, is raised gradually to the maximum, and after some minutes is slowly reduced and shut off. The duration of the current is about twenty minutes, but this time varies with the battery, and especially with the condition of the blood in the aneurismal sac. The needles should be removed in the order in which acted on, and with great care and gentleness. The patient should be recumbent during the operation, and should remain in a

condition of absolute repose for some hours subsequently.

The negative pole should consist of a *large*, well-moistened sponge, placed on the shoulder or side. The operator should be careful to pursue the order in the various points of manipulation above indicated.

Accidents.—If the proper strength of current is used, if the needles are well constructed, and if all the details are carried out efficiently, yet gently, no accidents are to be apprehended. If the current has too much heating power, as happened in one of the cases reported by Dr. Henry Simpson,[1] sloughing along the track of the needles, and sudden, fatal hemorrhage may be thus produced. If the power is insufficient, coagulation will not be effected. In withdrawing the needles, rarely on introducing them, coagula may be separated, carried into the circulation, and distant vessels be occluded. The symptoms resulting will depend on the vessel or vessels blocked. If the aneurism be situated on the ascending aorta, an embolus may enter the left carotid, rarely the right, and produce the phenomena of apoplexy, followed by right hemiplegia and aphasia. The same result might follow if the aneurism were at the arch. If situated on the innominata, the symptoms resulting would be those of apoplexy, followed by left hemiplegia without aphasia, or the subclavian or brachial blocked, the right arm would suddenly become intensely painful, cold, and weak. Occlusion of certain of the abdominal arteries, or of the femoral, would be produced by clots detached from an aneurism of the descending aorta. Fortunately, these are comparatively rare accidents, and still less common are the phenomena due to multiple embolisms.

[1] London Lancet, *supra.*

In withdrawing the needles, hemorrhage may occur. This will not happen unless the needles are too large, are too much heated, or are roughly handled. Owing to the condition of the tissues, sloughing may occur some hours or days after the needles have been withdrawn, and then a profuse hemorrhage terminate life. Or an inflammation of the sac and its contents may follow the process of electrolysis. This accident will be announced by chills, fever, increased pain, etc., and death occurs suddenly by the yielding of the sac.

Curative Results.—When clots form about the needles, the coagulation extends until finally an organized clot fills the sac. At first, some heat and tenderness are felt about the sac—a trivial inflammation which soon subsides under the action of cold-water applications. The tumor becomes firmer, shrinks in size, the pulsations diminish, and finally disappear, and at last a hard knot, merely, remains at the site of the aneurism. It should not be understood that a process of decomposition is effected by the needles. The sole purpose of their introduction is to bring about a coagulation of the blood, and it is to the organization of the clot that the cure is to be attributed. Thus, by the electrolysis of an aneurism, the same result is sought to be accomplished as by the other medical and surgical expedients.

Clinical Experiences.—Petrequin,[1] of Lyons, seems to have been the first to apply the method of electrolysis to the treatment of aneurism, his first case being an aneurism of the temporal artery, traumatic in origin. In the four years from 1845 to 1849, he gained in experience and perfected his method, the result being given in an important monograph which appeared in the latter year. Whilst Petrequin was engaged in these clinical

[1] Bull. Gén. de Thérap., tome xxxi. p. 65.

researches in Italy, a medical commission composed of Stambio, Guaghino, Tizzon, and Restelli, studied in animals the power of the electric current to cause coagulation of the blood. These experiments demonstrated that, although the negative pole possesses but little coagulating property, the positive, on the other hand, forms a coagulum, at first incomplete, but becoming in a short time solid enough to close an artery of the size of the carotid.[1] These experiences formed the basis of the method of treating aneurisms devised by Ciniselli, which consisted in the employment of the electric current to coagulate the blood in the aneurismal sac. The strength of current necessary was ascertained by the amount of water decomposed within a given time. The first needle introduced into the sac was connected with the positive pole, whilst the negative was placed near the aneurism externally; after five minutes he replaced the positive pole by the negative, and the former was then connected with the second needle, also introduced into the sac; after another period of five minutes the negative pole was connected with the second needle, and the positive transferred to a third needle; and thus on, each needle being made to pass alternately the current from the positive and negative poles respectively, always beginning with the positive. Treated in this way, of thirty-eight cases, a radical cure was not obtained in one, although in twenty-seven the cases were so far ameliorated that they were able to resume more or less fatiguing occupation for some months or years. Since the publication of Ciniselli's method and its results, a great many cases have been reported from Italy. In Germany, Fischer (Franz);[2] in France, Bernutz, Broca,

[1] Ibid., tome 93, p. 1 et seq. Paper by Dujardin-Beaumetz.
[2] Berliner klin. Wochenschrift, No. 45, 1874.

Dujardin Beaumetz,[1] and others; in England, Anderson,[2] Duncan,[3] Bastian, Clifford Allbutt; in this country, Sands,[4] Lincoln, Keyes,[5] and others, have also reported cases, so that now the experience gained may enable us to arrive at definite conclusions. In a lecture "On Electrolysis," Dr. Duncan, of Edinburgh, has given a tabular statement of the cases of aneurism treated by this method to 1879 (May).[6] His figures are as follows:

	No. of cases.	Cures.	Deaths.
Aorta,	37	6	3
Innominata, carotid, and subclavian,	13	3	6
External iliac,	2	1	0
Femoral, popliteal, and brachial,	29	16	3
Smaller vessels,	8	6	0
Totals,	89	32	12

Since the period included by Dr. Duncan, I have collected the following cases:

CASE 1.—Aneurism of ascending aorta. By Guisseppi Bulgheri, *Gaz. Med. Ital. Lomb.*, No. 13, 1876. Referred to by Virchow u. Hirsch's Jahresbericht for 1876. Sac of the aneurism consolidated, reduced in size, and apparently cured. Treated by the method of Ciniselli.

CASES 2 and 3.—*Ibid.* Same result in the second, but only improvement in the third case. Virchow u. Hirsch's Jahresbericht for 1877 contains an abstract of the three cases.

CASE 4.—Aneurism of the innominata. By Carlo Gallozzi, *Il Morgagni*, Settr. 1876, p. 585. Quoted by Virchow u. Hirsch's Jahresbericht for 1876. Electrodes applied externally, one on the tumor, the other adjacent. The current from eight elements of Leclanché was directed to the tumor for eleven minutes at a time. Five or six *séances* were had each day, and for eight days, a considerable diminution in the size and firmness of the tumor being the result.

CASE 5.—Aneurism of the left subclavian. By A. Martins, *Ibid.* The result was negative.

[1] Bull. Gén. de Thérapeutique, July 15, 1877.
[2] McCall Anderson, British Med. Journal, vol. ii., 1875, p. 517.
[3] Ibid., vol. i., 1876, p. 619.
[4] New York Medical Record, May 15, 1871.
[5] New York Medical Journal, July, 1871, p. 3.
[6] Brit. Med. Journal, vol. i., 1876, p. 620, op. cit.

CASE 6.—Aneurism of the aorta. Dr. John Homans, No. 16, 1876, of the *Boston Medical Journal*. The treatment by electrolysis was a failure.

CASE 7.—Aneurism of the aorta. Dr. Dujardin-Beaumetz, *Bull. Gén. de Thérap.*, Juillet 15, 1877. Very considerable improvement in the condition of the patient was the result.

CASE 8.—Aneurism of the aorta. Guimarez Pareira, *Gaz. des Hôpitauz*, 81, 1876. Reported "Cured."

CASE 9.—Aneurism of the aorta. Dr. H. Bowditch, *Boston Medical Journal*, No. 2, 1876. The case was much improved.

CASE 10.—Aneurism of ascending aorta. Dr. Henry Simpson, *The British Medical Journal*, vol. 2d for 1877, July 14. Failure.

CASE 11.—Aneurism of the aorta and innominata. The same reporter and source as No. 10. In this case the result was more favorable for a time; the tumor was greatly reduced in size and consolidated, but electrolysis was again employed with a battery furnishing more heating power. Suppuration ensued in the track of the needles, and the aneurism was laid open, death ensuing by hemorrhage.

CASE 12.—Aneurism of the aorta. Mr. H. L. Brown, *The Lancet*, Oct. 26, 1878, p. 584. A large tumor was apparently consolidated by two needles connected with the positive pole, and a cure was supposed to have been effected. The man, escaping from the hospital and taking no precautions, suffered a relapse.

CASES 13, 14, and 15.—Three cases of intrathoracic aneurism. Dr. Gregor Ottoni, *Annali univers di med.*, Nov. 1878, p. 442. Quoted in Virchow's u. Hirsch's Jahresbericht for 1878. The method of Ciniselli was pursued. In two the results were negative, but in the third very great improvement resulted.

CASE 16.—Aneurism of the ascending aorta. Dr. Bucquoy, *L'Union Médicale*, No. 20, 1879. Treated by Dujardin-Beaumetz's modification of Ciniselli's operation, with a very favorable result.

CASES 17, 18, 19, and 20.—These cases of intrathoracic aneurism, treated in this country by Drs. Sands, Lincoln, Keyes, and Pepper, were probably not included in the report of Dr. Duncan. In these cases improvement was the usual result, but no instances of actual cure occurred.

CASE 21.—Aneurism of aorta. Dr. Ord, St. Thomas's Hospital Reports, New Series, vol. x.

A review of the cases affords much encouragement for the future success of the method of electrolysis in the treatment of intrathoracic and abdominal aneurisms. We are not yet in a position to give accurate results. In most of the cases reported "improved" or "cured" the condition of the patient subsequent to the immediate

results of the operation is not known. This is especially true of the Italian cases. The cures reported in some instances are so extraordinary that we may well entertain doubts about their permanence. The best results have been obtained by the Italian operators using the method of Ciniselli. This, as modified by the French operators, promises to be the method of the future. There are yet differences of opinion as to the form of battery best suited for this purpose. Anderson[1] says the battery should "have large cells, to increase the chemical effects." On the other hand, in one of Simpson's cases, an untoward result, when the promise of success was bright, resulted from a change to a battery of larger cells, suppuration occurring in the tract of the needles. The intensity should be great rather. I have already indicated the degree of intensity necessary. With an absolute galvanometer, graduated in milliwebers of current strength provided the operator, an exactness of results may be arrived at hitherto unattainable. To this our efforts should now be directed.

Numerous cases of *cirsoid aneurism* have been reported cured. Typical examples have been published by Mr. Hulke.[2]

In *cystic tumors*, *cystic degeneration of the thyroid gland*, and *echinococci of the liver*, very admirable results have been obtained from electrolysis. Cystic tumors of the neck have been reported cured by Amussat,[3] Ultzmann,[4] and others; cystic bronchocele by Smith,[5] Althaus,[6] and others. Both needles are introduced and

[1] The Medical Times and Gazette, 1875, vol. ii. p. 516.
[2] Ibid., June 9, 1877, p. 612.
[3] Bull. Gén. de Thérap., Oct. 15, 1872.
[4] Wiener med. Presse, Nos. 42, 43, 44, 46, 1876.
[5] New York Med. Record, Aug. 7, 1875.
[6] British Med. Journal, 1875, vol. ii. p. 605.

kept near each other, and the current is allowed to flow until the contents are in part decomposed.

Very promising results have been obtained by Semeleder[1] and Clemens[2] in the treatment of *ovarian cysts* by electrolysis. Fieber[3] failed in an apparently favorable case. This method of treating ovarian cystic tumors deserves more attention than it has hitherto received, notwithstanding the remarkable success which has attended abdominal section. Unilocular cysts with simple contents are more favorable than the multilocular cysts with compound contents. The treatment should be undertaken early, before the tumor has attained a great size. The method of procedure is simple. The needles must have the requisite length, and be carefully insulated. The tumor, well depressed into the iliac fossa, must be carefully steadied before the needles are inserted, and the intestines must also be pushed aside. The needles should penetrate one or two inches into the cyst, and their points made to approximate within an inch, to lessen the resistance. The duration of the application depends on the character of the fluid to be decomposed, and may be stated as from fifteen minutes to one hour.

Solid tumors, as goitre,[4] enlarged submaxillary glands,[5] subcutaneous erectile tumor,[6] and nasal polypi,[7] and similar growths have been repeatedly cured by electrolysis. Good results, although it cannot be affirmed that any cures have followed the electrolysis of uterine

[1] Wiener Presse, loc. cit., Nos. 50 and 52.

[2] Deutsch. Klinik., Nos. 6 and 7, for 1875.

[3] Wiener Presse, *supra*.

[4] Wahltuch, Med. Times and Gazette, Jan. 28, 1877.

[5] Davis, Phila. Med. Times, Oct. 2, 1871.

[6] Archives of Elect. and Neurol., vol. ii. p. 74.

[7] Bruns, Berliner klin. Wochen., Nos. 27 and 28, 1872; 32, 1873.

fibroids. The galvanic current, made to traverse these growths, has a most beneficial effect on the condition of the patient; it relieves pain, diminishes the accompanying congestion, and retards the growth. *Polypi*, *nævi*, *sebaceous tumors*, and similar new formations are promptly cured by electrolysis.

In *stricture of the urethra*, remarkable results have been obtained by Newman,[1] Tripier,[2] Frank,[3] and others. Insulated electrodes of suitable shape are passed into the urethra so that the point of the instrument engages the stricture. The other electrode is applied to the perineum or penis, in such a position that the stricture must be included within the circuit. An electrolytic decomposition takes place, and the obstruction is gradually removed by absorption. The negative electrode should communicate with the stricture.

Neftel,[4] of New York, and Mussy, of Cincinnati, report cases of *malignant disease* (apparently) which were made to disappear by electrolysis. The growths so decomposed appeared to be examples of epithelioma; but as these results have not been confirmed by others, it is generally held that errors of diagnosis were committed. Beard,[5] who has had encouraging experience in the treatment of malignant disease by this method, proposes a new plan, which he entitles "working up the base." According to this, the sound tissues immediately subjacent to the tumor are transfixed by the needles, and the source of supply to the new formation is thus acted on. Rockwell[6] reports good results from Beard's method in a case of cancer of the breast.

[1] Archives of Electrology and Neurology, vol. i. p. 18.
[2] Onimus et Legros, op. cit.
[3] New York Med. Record, Feb. 2, 1874.
[4] Virchow's Archiv, vol. lxx. p. 171.
[5] Archives of Electrology, etc., vol. i. p. 74.
[6] Archives of Electrology and Neurology, loc. cit.

I have had remarkable results in the treatment of those *fibroid tumors* of the breast which are so often associated with displacements and other diseases of the uterus, and accompanied by neuralgia of the cervical plexus. I have in these cases used labile and stabile applications to the nerves and to the breast, and have not introduced electrolytic needles. Of six cases thus treated, four were cured, and in the others the time was insufficient.

In *extra-uterine pregnancy*, the life of the fœtus has been destroyed by electrolysis, the safest and best expedient for this purpose. By thus arresting the development of the fœtus, the danger of rupturing its enveloping sac is averted. Needles, such as have been described, are introduced into the sac, and a current strength of from 10 to 30 milliwebers is passed for a few minutes. The death of the fœtus has also been accomplished by transmitting the shock of a Leyden jar charged with static electricity, but this is a less certain procedure than the method of electrolysis.

Lastly, excellent results have been obtained by electrolysis in *hydrocele*, by Rodolfi,[1] who first proposed it, by Erhardt,[2] Frank,[3] and myself. In the treatment of this affection, two insulated needles, connected with the electrodes, are introduced into the sac, and their points are brought within a half inch of each other, when the current is turned on. Decomposition ensues, according to the laws of electrolysis, and absorption takes place. Rodolfi reports eight cases, with the following results: three were radically cured, two required a second operation, and three were failures of greater or less extent.

[1] Virchow u. Hirsch, Jahresbericht for 1872. [2] Ibid.
[3] Archives of Elect., loc. cit., vol. i. p. 170.

CHAPTER II.

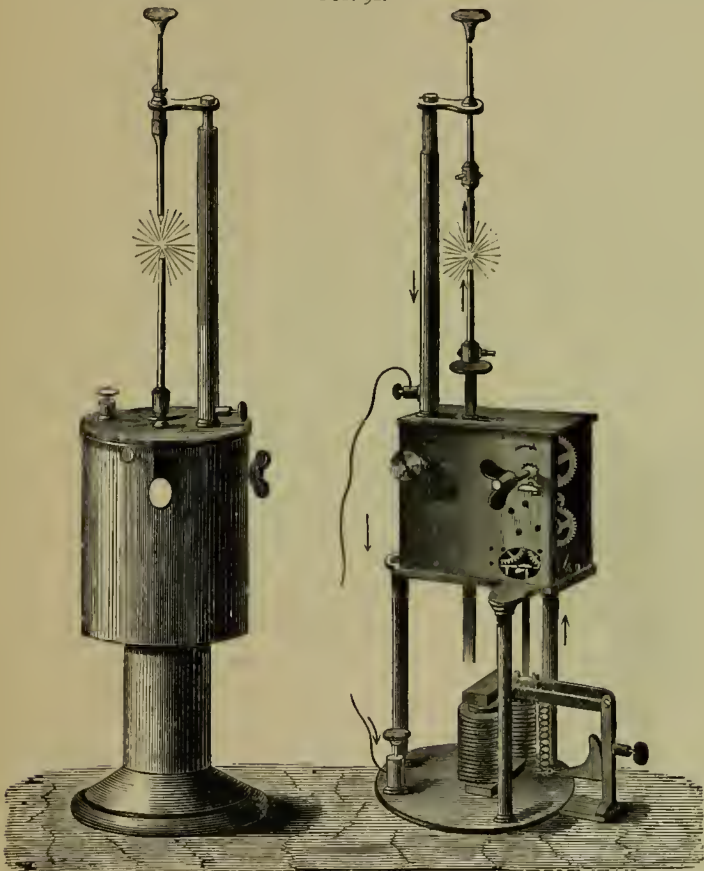
MEDICAL ELECTRIC LIGHTING AND HEATING.

Electrical discharge takes place, as has been set forth, by conduction, by convection, and by disruption. In the ordinary application of galvanism, the electricity passes from one electrode to the other by conduction. If, for the usual electrodes, needles are substituted, and they are separated by a greater or less interval, the solids or fluids acted on are decomposed into their constituent elements. The process of discharge is then by convection, and it is designated, in the language of Faraday, *electrolysis*. Although here the needles are not in actual contact, there is a route of communication —the solid or fluid into which the needles penetrate— by which the current passes.

If a large quantity of galvanism is made to pass between the terminals, separated by a short interval in the air, or is made to traverse an inferior conductor, as platinum wire, the discharge is said to be by disruption and is attended with light and heat. This method is employed in electric lighting. When the terminals are of carbon, the molecules of the intervening stratum of air, but especially fine particles of carbon, are rendered incandescent, and the brilliant light is due to this. A mechanical device is necessary to keep the terminal carbons at the proper interval, since a gradual erosion of the carbon point is going on. In Dubosq's lamp, and others of the same pattern (Fig. 92), a clock-work is so arranged as to effect this object.

If the terminals are connected by platinum or a fine film of carbon, the large quantity of electricity passing is so condensed as to heat the material conducting it to an intense degree, which renders it brilliantly luminous.

FIG. 92.

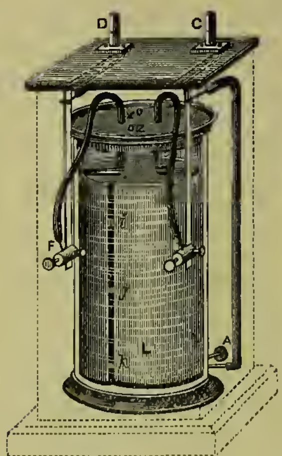


Electric lamps.

This method is utilized in galvano-causty, and has lately been ingeniously arranged for purposes of medical illumination. It is most convenient to consider the latter first.

It has recently been ascertained that a certain form of elements may be charged by another battery, so as to furnish a current of considerable quantity for several hours. The principle is that of polarization, and may be explained as follows: When two strips of platinum in water are made the terminals of a battery, it is found that the strip connected with the anode is covered with minute bubbles of oxygen gas, and the other, connected with the cathode, is covered with bubbles of hydrogen gas. If now the strips are separated from the battery, and connected with a galvanometer, it is at once seen that a current of polarization is passing from the hydrogen to the oxygen through the liquid, which is opposite in direction to the battery current. It has been further ascertained by Planté that this polarization current may last a long time if the plates are large enough. Availing himself of these facts, Planté has constructed "*secondary cells*," as they are entitled, which furnish a large volume of electricitiy, sufficient, indeed, to be used for the purpose of illumination and galvano-causty. As the principle here involved is of great importance, and as it is likely to enter largely into the construction of medical electrical apparatus, the reader ought to have a clear comprehension of it and of the apparatus. The following is the arrangement of Planté's cell (Fig. 93): "It consists of two plates of lead rolled into spirals, *L*, one within the other, but kept from contact by means of strips of

FIG. 93.



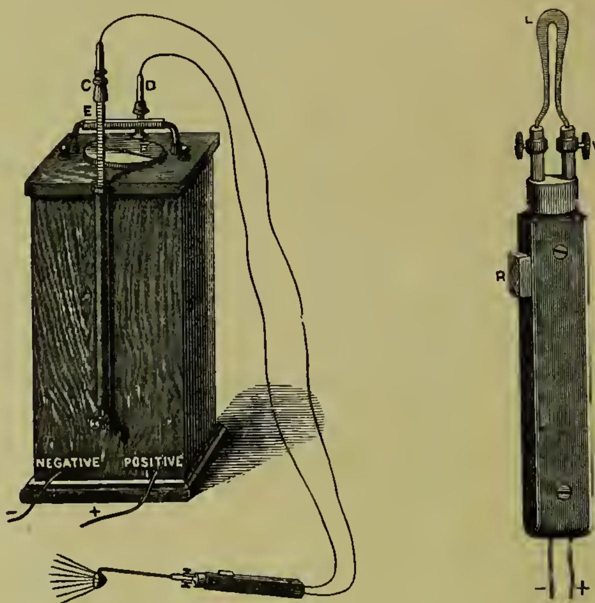
Planté's cell.

vulcanite, *i*, *j*, *k*. They are connected to the polarizing battery by means of two wires, *E*, *F*, and two terminals, *C*, *D*, which give the polarization current. To set the battery in action, we have simply to fill this secondary cell with water containing ten per cent. of sulphuric acid, and connect it by means of the binding screws at *E*, *F*, to a battery of four Daniell cells, or two Bunsen's." Continuing in action thus for several hours, the secondary cell is found to be charged. To draw off the polarization current, it is only necessary to attach the necessary electrodes to *C*, *D*, when the current will flow until that stored up is disposed of. Batteries are now constructed in accordance with this principle on a large scale. They are called "accumulators," "storage cells," etc. In France, the accumulators of Faure are largely used, and have been introduced into this country. The electric energy stored up in these cells is given out when required. Their power is limited only by size. Charged in Paris, some of the Faure accumulators have been utilized on the voyage for lighting the ship, and others have since been employed in mechanical work. Obviously, the power thus obtained can be transported to any point, and used for any kind of mechanical work.

Availing himself of this principle, M. Trouvé has contrived the *electrical polyscope*. Constructed as above described, it is contained in a quadrangular case about one foot in height, and six inches across. At the bottom are the wires + and — for attaching the battery which charges the polyscope, and at the top are the poles for attaching the electrodes or the handle (Fig. 94). There is also a rheostat, *A*, for regulating the resistance or strength of the currents, and a galvanometer, *B*. The handle is of a form usually employed for galvano-caustic

operations, and has a sliding button, *R*, for making and breaking the circuit. The handle is represented carrying a platinum knife, and has binding screws at *V* for attaching either knives, cautery domes, or mirrors for

FIG. 94.



Trouvé's polyscope.

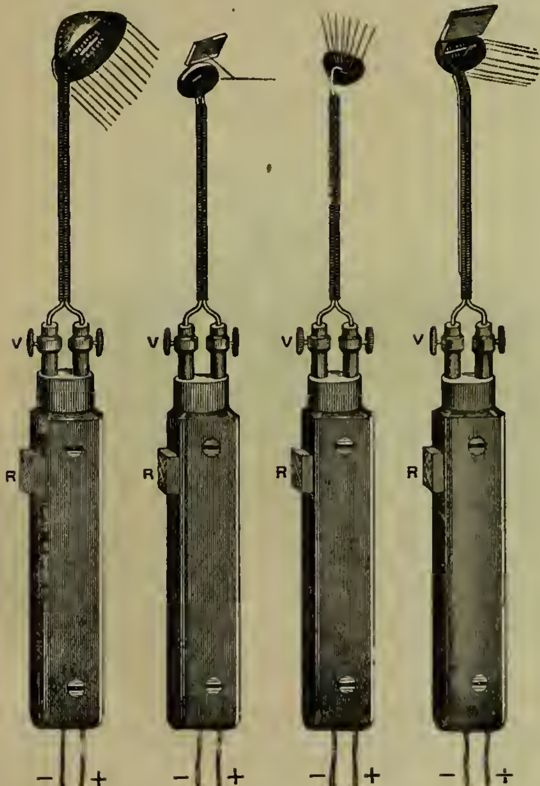
illumination. Figs. 95, 96, 97, and 98 represent mirrors for illuminating the throat, larynx, mouth, etc., and there are also illuminators for the eye, ear, and internal cavities.[1] The polarizing current stored up has sufficient volume for the operations in galvano-caustic surgery, and for the various kinds of illumination. The night before the polyscope is to be used, the charging battery is attached, and the current is allowed to flow. On the

[1] Can be obtained from James W. Queen & Co., of this city, who have the apparatus in stock.

following morning the polyscope will be found to contain a sufficient charge for the purpose of illumination or galvano-causty.

Although the apparatus of Trouvé is likely to supersede all other galvano-caustic instruments, it is necessary to enter into some details regarding those now in use. In the construction of a battery for this purpose

FIG. 95. FIG. 96. FIG. 97. FIG. 98.



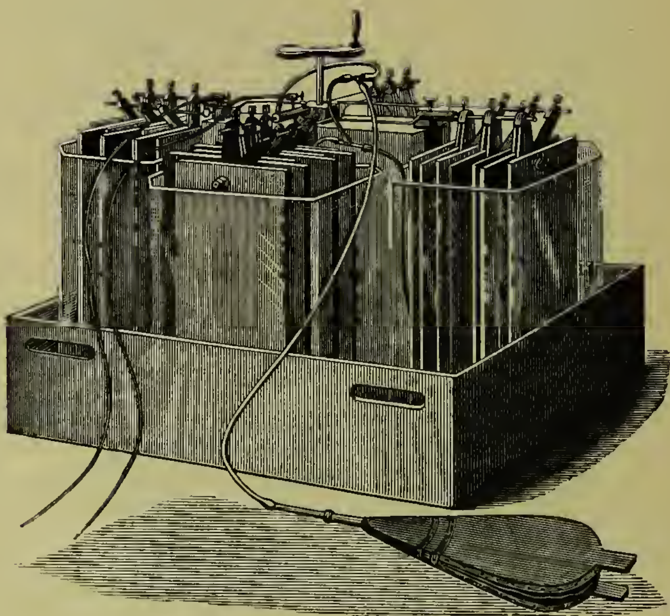
Larynx reflectors.

the quantity of electricity is the consideration which governs the arrangement. It has already been pointed out that the quantity is determined by the size of the

plates and intensity by their number, and that the elements may be combined for quantity as well as intensity. According to Ohm's law, the current is equal to the electro-motive force divided by the internal and external resistance. In the galvano-caustic battery, the plates must be large, so as to expose as much surface as possible to the chemical action, and the internal resistance must be diminished as much as possible by bringing the plates as near together as may be without touching.

The apparatus now used for galvano-causty consists of the battery with a few large elements, or a number

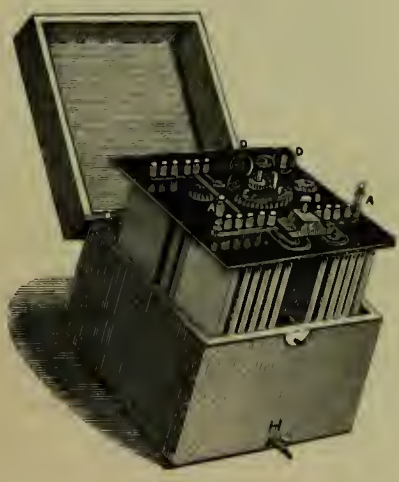
FIG. 99.



of small elements connected for quantity; the cable or conducting wires, and the handles for knife, cautery, or loop. The principles involved are the same, what form

soever the combinations may take. The caustic battery first devised was that of Middledorpf, described in his classical work on *Galvano-causty in Operative Medicine*, published at Breslau in 1854. On the continent the combinations of Bunsen and Stöhrer, in France Bunsen's, and now Trouvé's, and in England Stöhrer's modified by the local dealers, are the forms in use. In this country the battery of the Galvano-faradic Company, Piffard's, and Byrne's, are those chiefly employed. The first named is composed of large zinc-carbon elements (Fig. 99), immersed in a bichromate of potash solution,

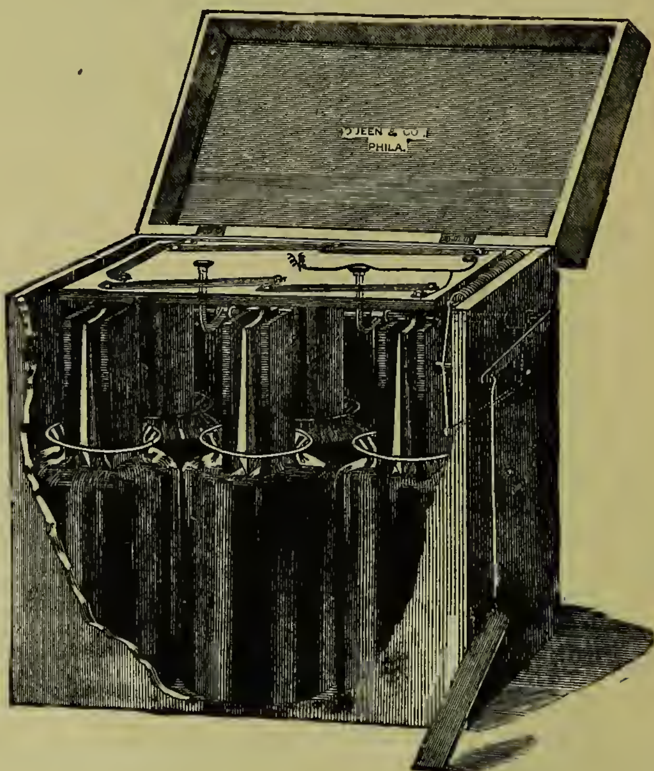
Fig. 100.



which is kept agitated by the bellows to prevent polarization of the hydrogen and to maintain the chemical activity. Piffard's battery is composed of large zinc-carbon elements, which are contained in cells of vulcanite, and can be suspended on a movable arm screwed into the box. When lowered into the fluid, the top of the elements, which is made of hard rubber, contains two lateral bars supporting them, and which permits a rock-

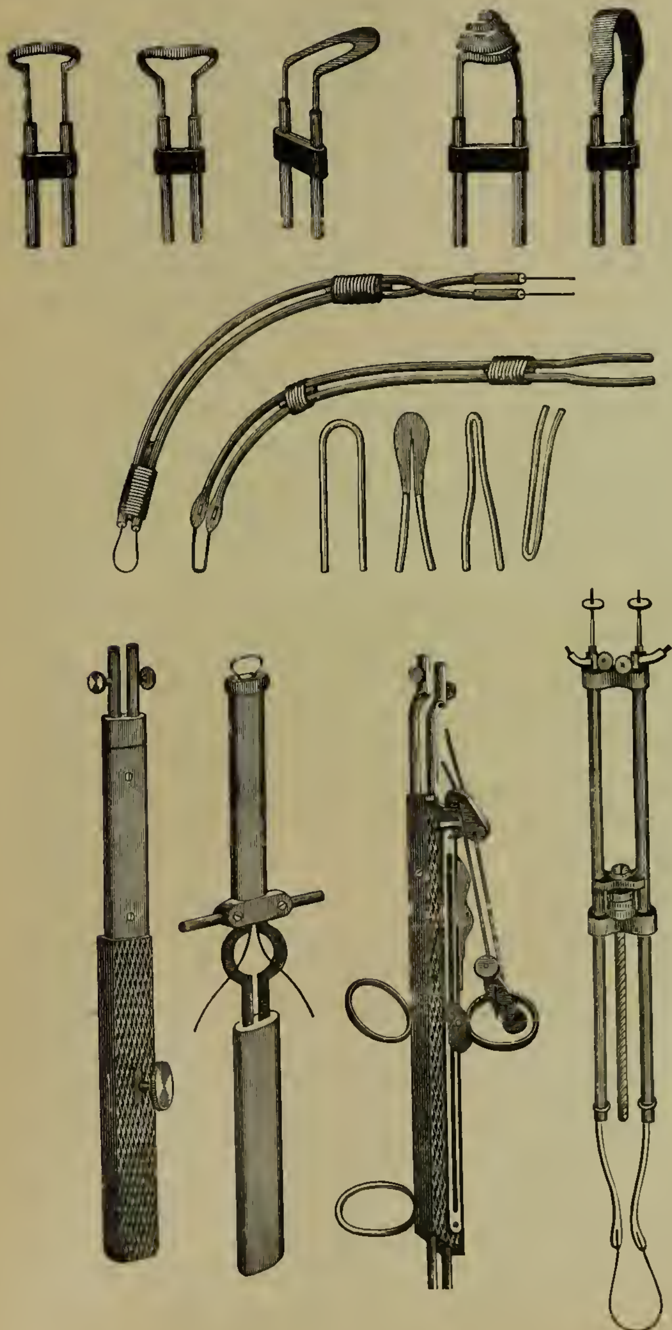
ing motion to keep this exciting fluid agitated. This is a more efficient combination than that of the Galvano-faradic Manufacturing Company. Still more effective is the battery of Dr. Byrne (Fig. 100), which consists of small elements united for quantity, thus opposing a larger surface to the action of the exciting fluid than can be effected by merely large plates. This battery consists

FIG. 101.



of zinc-carbon cells in a case six inches long, nine inches high, and five inches wide. Each plate is composed of a number of smaller ones so united as to constitute one, and all are contained in one jar. They are also placed

FIG. 102.



Galvano-caustic knives, cauteries, and loops.

in close juxtaposition, from the one-sixteenth to the one-eighteenth of an inch apart, thus diminishing the internal resistance. The success of Dr. Byrne's battery strongly supports the accuracy of that theory which ascribes superior activity to the small elements combined for quantity. The storage cells may be used for this purpose also. Messrs. J. W. Queen & Co. have a convenient and easily worked cell, which has a treadle attachment, and which is used by them for running an electric motor (Fig. 101).

The conducting wires should have sufficient size to offer the least resistance to the passage of the current, and should be as short as compatible with their usefulness. The platinum electrodes are of various forms, for adaptation to the conditions present. On page 269 are represented the knives, cauteries, loops, etc., employed in this branch of surgery (Fig. 102).

The knives are variously shaped, so as to be useful for cutting, scraping, or gouging. The loop is attached to a ratchet-wheel, by the revolutions of which it is equably shortened as it cuts through the tissues. The "dome cautery" consists of a spiral of platinum wire wrapped about a porcelain button. When the wire is rendered hot, the porcelain is heated correspondingly.

Before undertaking an operative procedure, the condition of the battery must be ascertained. It must be in good working order, of course, and all of the necessary appliances at hand. The amount of electricity required will be determined by the size of the wire or knife to be used, and the amount of tissues to be cut through. This may be closely approximated by trying the knife or wire on a piece of meat. The depth to which the elements are immersed, or the number of elements required to produce a given quantity of electricity, once known, it

would seem a needless refinement to try the strength of the battery each time, but experience has shown that it is preferable to do so. If the quantity is too great, the wire may be melted; if too little, the operation may have to be suspended. The wire must be incandescent. If it cut through too quickly by reason of too great heat, there is danger of hemorrhage; if too slowly, the surrounding parts inflame.

The advantages of the method are numerous and important, and the pain which attends the operation is not great, and may be almost wanting. Shock is less than by other methods. If the wire be at the right temperature, there is no hemorrhage, the vessels being effectually sealed as the operation proceeds. It follows that the electric knife may be used in positions where the ordinary cutting or tearing operations could not be performed. The loop, cautery, or knife is placed in position first, and then heated to the requisite point, and is cooled again before withdrawal. In general, it may be stated that galvano-causty is applicable to the removal of growths from internal cavities, of cancer in any accessible situation, and of morbid products where hemorrhage is to be feared. The more abundant the experience (Dr. Byrne, Dr. Bryant), the more decided the approval of the method. The great obstacles to the development of the method are the care and time requisite for the management of the battery, and the failures which may take place at a critical juncture in the best hands. In setting forth the work done in the field of galvano-caustic surgery, it will be most convenient to treat of the maladies requiring the loop, the knife, and the cautery.

The Loop.—Before the loop is used in any case, it should be carefully tested on a piece of meat of a size

corresponding to the growth to be removed. If the external integument is embraced in the tissues to be divided, it is better to cut a groove with the platinum knife at a white heat, in which the wire may be placed. The wire should be of a size adapted to the work to be done, and the battery should be capable of heating the wire to the necessary point, and maintaining it there during the time required. The wire should be put in position before turning on the current, and the ratchet-wheel should be slowly worked, giving ample time for the division and searing of the tissues. Obviously the caustic loop is adapted to the removal of deep-seated *polypi* in the nose, ear, larynx, uterus, rectum, etc. In his elaborate work on galvano-caustic, Voltolini[1] reports a large number of cases of *polypi of the larynx*, *nose*, *and ear*, easily, quickly, and safely removed by the loop. Amputation of the neck of the uterus has been performed in the most satisfactory way by Whittaker,[2] Byrne,[3] and others. No one has applied himself more thoroughly to the galvano-caustic operative methods than Bryant,[4] and he reports various examples of amputation of the tongue, penis, and of hemorrhoidal tumors, accomplished in the most admirable manner by the galvano-caustic loop. It would seem needless, indeed, to multiply the references to this method. On all hands it is regarded as the most efficient, and at the same time safest method, for, while no blood is lost, no shock is experienced.

In the operation for the removal of a polypus from

[1] Die Anwendung des Galvanokaustik im innern des Kehlkopfes und Schlundkopfes sowie in der Mund- und Nasenhöhle und den Ohren, etc., von Rudolph Voltolini, Wien, 1872, p. 317.

[2] The Cincinnati Clinic, Sept. 1872.

[3] The Electro-cautery in Uterine Surgery, New York, 1874.

[4] Clinical Lectures on Bloodless Operating. The Lancet, Feb. 28, 1874.

the cavity of the larynx, the patient must be trained into a proper tolerance of the instruments. The application of the loop is, of course, guided by the mirror. A long, properly curved, double canula, with the loop attached is necessary, and this is fixed to the handle with its ratchet-wheel or screw for drawing on the wire. The loop as guided by the mirror is thrown over the polypus, then the current is turned on, and in a short time the pedicle is severed. If the loop is at a white heat, the division of the tissues is accomplished too speedily, and hemorrhage may result. Mr. Bryant advises that the wire be maintained at a dull red rather than a white heat. In the operation for removing a polypus of the auditory canal, or of the nose, suitable specula and loops are required, but the form of handle may continue the same. In the case of hemorrhoidal tumors of the rectum, the procedure is as follows: The tumors are drawn down and held by a tenaculum or single or double hook if in a position to be so secured, with or without the previous adjustment of a Sims's speculum; the loop is passed over the tumor and pressed well down to its base or point of attachment, and at the same time tightened to prevent slipping; the wire is heated to a dull red, and made to cut its way through slowly to avoid after-hemorrhage.

In regard to the operation for the removal of the tongue by the galvanic loop or écraseur, Mr. Bryant expresses himself as follows:[1]

"There are no operations of importance that the surgeon has to perform which have been more benefited and simplified by the introduction of the galvanic cautery than those upon the tongue; for there are none in which,

[1] The Lancet, loc. cit., Feb. 28, 1874, p. 291.

without its use, hemorrhage is more troublesome or dangerous, and there are none with its use which more satisfactorily exhibit its bloodless character. Indeed, before the introduction of the galvanic cautery or écraseur, operations on the tongue were very rarely performed." In the same lecture he further says: "By the use of such instruments carefully employed, no fear of bleeding need disturb the mind of the operator; and what was formerly a very serious measure has become comparatively a simple one." Again he remarks: "I will say again what I have said before, that, of all ways, the removal of the tongue by the galvanic écraseur is the one to be adopted." In the performance of the operation for amputation of the tongue for cancer, Bryant directs that the diseased part be isolated by passing beneath it through the healthy tissues some long pins, ivory pegs, or curved needles in handles, and the loop passed behind the pins, the tongue being well drawn forward and firmly held, and the mouth kept open by a suitable gag. He further directs that the wire of the loop be "thick or twisted," his preference being for the twisted wire, and that "it should not be heated beyond a red heat, and the redness ought to be of the dull kind. Above all, the process of tightening should be very slowly performed, the wire of the écraseur being screwed home only as it becomes loose by cutting through the tissues."

In the lecture from which I have quoted, Mr. Bryant reports eleven cases of cancer of the tongue thus operated upon, and he concludes that "the removal of a tongue wholly, or in part, for cancer is a justifiable proceeding, and that the sooner the operation is performed after the diagnosis of the disease has been made, the greater are the prospects of a long immunity from the disease, or a complete cure."

Mr. Bryant also reports cases of amputation of the penis for cancer, in which he highly commends the bloodlessness and the freedom from pain of the galvano-caustic loop. His lecture includes fibro-cellular tumors of the labia, epithelioma of the lip, etc. When the growth is without a pedicle, he isolates it by passing pins or acupuncture needles beneath it, and thus confines the wire to its proper course.

The Knife.—No one has used the galvanic knife more, nor carried its applications to greater perfection, than Dr. Byrne,[1] of Brooklyn. He has especially attained to unequalled success in the treatment of *uterine cancer*, employing the knife and scraper, and carrying the incisions deep enough to insure the removal of all the diseased parts. The advantage of the galvanic knife consists in the freedom with which it may be used without the production of hemorrhage. The platinum knife can be shaped to any desired form. It should be put into position before the heating begins, and cut slowly, giving ample time to secure closing of the vessels.

One of the most brilliant operations ever performed with the galvanic knife is that described by Dr. Gaillard Thomas,[2] of New York. It was a case of *tubal pregnancy*, the cyst being reached through the vaginal roof. Dr. Thomas employed the platinum knife heated to a white heat, and succeeded in reaching the sac without causing any loss of blood.

Tracheotomy has now been performed a number of times by the galvanic knife, no hemorrhage resulting. One method consists in first transfixing the tissues, including the trachea, and then heating the wire sufficiently to cut through. This, however, is not so neat and effi-

[1] Electro-cautery in Uterine Surgery, loc. cit.
[2] The New York Medical Journal, June, 1875.

cient an operation as cutting through with the galvanic knife. *Cancer of the mamma* may also be removed as other external morbid growths by the same means. The special indication for the galvanic knife is the existence of deep-seated disease where, if hemorrhage occurs, it may be difficult to arrest it. Uterine cancer, tubal pregnancy, and tracheotomy are operations especially adapted to this method.

The Cautery.—Platinum wire, coiled about a cone of porcelain, constitutes the "dome cautery." These are of various sizes. Platinum wire folded on itself is a convenient cautery for small objects. Heated to a dull red or white heat, the cautery rapidly destroys the tissues of the morbid growths, or the unhealthy surface. It is used for the destruction of small *polypi*, *nævi* (Paul Bruns,[1] Nélaton[2]), *cancer*, *hemorrhoids*, etc. It is also a neat, effective, and but slightly painful method of reducing the size of *hypertrophied tonsils*. Prolapse of the rectum, fistula in ano, hemorrhage from a wounded surface, etc., are maladies to the relief of which the cautery is especially applicable. In prolapse of the rectum, a vertical V-shaped portion of the prolapsed tissue is clamped, cut off with scissors, and then the surface is cauterized by the galvanic cautery. The surface of the fistula is cauterized by the platinum wire, and is then ready to unite, which it usually does. Another operation consists in cutting through the fistula with the galvanic loop. The cautery raised to a dull red heat is an excellent means for arresting hemorrhage—general oozing, when it is deep-seated.

It is conceded by all who have had experience with

[1] Berliner klinische Wochenschrift, Nos. 27 and 28, 1872, and No. 32, 1873.

[2] Comptes Rendus des Séances de l'Académie des Sciences.

the galvano-caustic apparatus, that no method can be more satisfactory. The sole disadvantage is the trouble attending the management of the battery. It is probable that future modifications in the dynamo machine will result in the construction of one entirely adapted to the needs of medical and surgical practice.

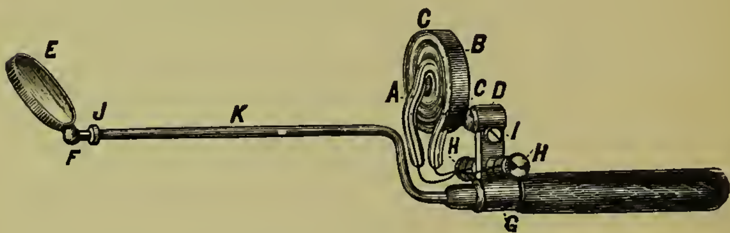
THE ELECTRIC LARYNGOSCOPE.—By this term is described a new reflecting laryngoscope mirror, invented by Dr. A. Wellington Adams,[1] of Colorado Springs. This is composed of a throat mirror *E* attached by a ball-and-socket joint *F* to the shank *K* and handle. Fixed to the handle by a shaft which permits complete rotation is a vertical support *I* having a short horizontal arm *C D*, to which by a ball-and-socket joint is attached the illuminating apparatus. In a brass case *B* is contained "a glass carbonic acid tube bent in the form of a spiral, and having a platinum wire hermetically sealed within it, *A*, and at the back of the case and behind the vacuum tube is a plane concave mirror with a focal distance equal to the space between it and the position of the throat mirror upon which it is intended to reflect the rays of light emitted by the spiral vacuum tube." "Attached to one end of the handle is the shank, made of some light metal, and bent in such a way as to bring the throat mirror attached to its free extremity upon a level with the spiral vacuum tube." The platinum wire of the vacuum tube can be connected with the wires of a battery by means of the binding screws *H H*. The whole arrangement is shown in Fig. 103.

Dr. Adams advises that the electricity be furnished by a Ruhmkorff coil, worked by three Grenet cells. "For operating the instrument, however," he says, "I prefer an equivalent number of Leclanché cells, as this form of

[1] Archives of Laryngology, vol. i. No. iii. p. 268.

battery requires no special attention or renewal from one month to several years, according to use." When the connections are made with the battery, "a brilliant white light is emitted from the glass spiral," and "this light has neither heat nor gas, and is of such concentra-

FIG. 103.



Adams's electric laryngoscope.

tion and intensity as to illuminate the respiratory tract down to a point nearly an inch below the bifurcation." The same principle may be applied to the otoscope, the ophthalmoscope, and other instruments for illumination. Dr. Adams deserves the greatest credit for his skill and ingenuity.

PART VI.

THERMO-ELECTRICITY.

CHAPTER I.

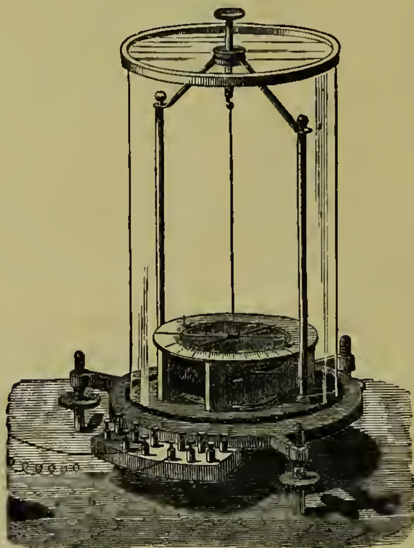
PRINCIPLES.

When a current of electricity meets an obstruction in its course—as when a large volume of electricity is made to pass through a small platinum wire—heat is developed. Conversely, when the conduction of heat in the course of a conducting circuit is obstructed, electricity is developed. The electrical current thus originated is known as *thermo-electricity*, and was first demonstrated by Seebeck so long ago as 1822.

To demonstrate the phenomena a sensitive galvanometer is necessary (Fig. 104). If the wires of such a galvanometer are connected with a straight platinum wire, the latter may be heated at any point distant from its connections without producing the smallest movement in the needle of the galvanometer; but "if the wire be made into a loop, its molecular tension at this point is slightly altered, and if heat be applied close to the loop and to the right of it, a current will flow through the apparatus from right to left, owing to the irregularity of the conducting power, and the disturbance in the regularity of the transmission of the force from the hotter to the colder portions. These effects are still more readily

produced by dividing the wire into two portions, and coiling each extremity into a flat spiral. If one of these spirals be heated to redness, and be brought into contact

FIG. 104.



Egerton's universal galvanometer for determining intensity or quantity.

with the cold spiral, deflection of the needle of the galvanometer immediately follows, in a direction which indicates the flow of a current from the hotter to the colder portion."[1] Metals having an inferior conductivity of electricity, in consequence of a crystalline structure, are especially suited to the demonstration of these phenomena. Thus, if bismuth and antimony are united together so as to form a ring—a closed circuit—(Fig. 105), and one of the junctions is heated more than the other, a current of electricity is developed, the direction of which is the same for rings of these metals, but

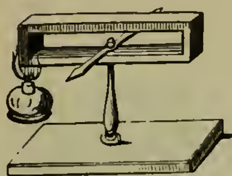
[1] Miller's Chemical Physics, p. 481.

differs in different combinations and also by the degree of heat. The same phenomena are also exhibited in the case of a rectangular bar (Fig. 106), composed of two dissimilar metals, bismuth and antimony. The strength of the current, for a given temperature, is different with the different metals. To indicate varia-

FIG. 105.

Ring of bismuth and antimony.

FIG. 106.



Bars of bismuth and antimony. Deflection of the needle on heating a junction.

tions and differences in temperature, the thermo-electric combinations are more sensitive than any other yet devised. The following list is a thermo-electric scale originally devised by. Becquerel. The metals are arranged in such an order that if any two constitute a couplet when joined, and are heated at the point of junction, the current will pass from the higher on the list to the lower.

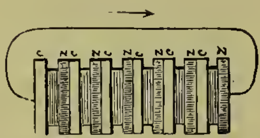
Bismuth,	Gold,
Platinum,	Silver,
Lead,	Zinc,
Tin,	Iron,
Copper,	Antimony.

It follows that a combination of bismuth and antimony elements will furnish the strongest current. Further experience has shown that certain alloys possess much greater electro-motive force. Thus Lombard[1] has shown

[1] The Regional Temperature of the Head, by J. S. Lombard, M.D. Lond., H. K. Lewis, 1879, p. 19,

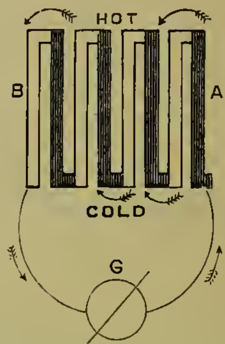
that the best combination is an alloy of antimony for one bar, and bismuth alone for the other bar. A number of these arranged in order, form a *thermo-electric pile* or battery (Fig. 107). When to the pile or battery

FIG. 107.



Thermo-electric pile.

FIG. 108.



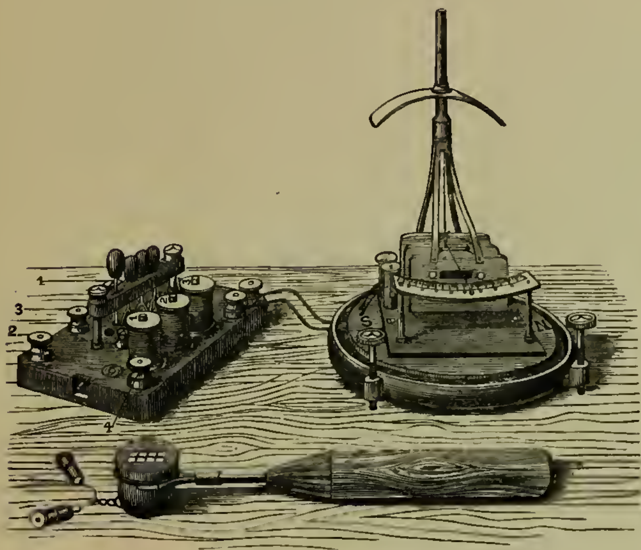
The thermo-electric multiplier.

a galvanometer is added, the whole constitutes a thermo-electric multiplier (Fig. 108). The shaded bars, A, are intended to represent the bars of antimony or an alloy of antimony, and those given in outline, B, represent bismuth. The upper surface, marked *hot*, is heated, whilst the under surface, marked *cold*, is kept cool. The difference in temperature originates a current, which, starting from the antimony, passes to the bismuth, and thence to the galvanometer G. As perfected by Lombard, the thermo-electric multiplier becomes excessively sensitive to changes of temperature. When the outer face of the battery is applied to a warm surface, an immediate deflection of the needle occurs. The thermo-pile of Lombard consists of eight pairs of bismuth and an alloy composed of 64.43 parts of antimony and 35.57 of zinc. The pairs are fitted into ebonite caps eight-tenths of an inch in height, and the same in diameter.

Two piles are necessary to make comparative observations.

As the size of the elements—the bars of bismuth and antimony—does not determine the effect, there is no

FIG. 109.



Lombard's thermo-electric apparatus.

advantage in having large elements, except as in so far the conduction is increased. The best arrangement of the pile for uses connected with medical practice, is that of Lombard.

CHAPTER II.

MEDICAL USES OF THE THERMO-ELECTRIC PILE.

THE mercurial thermometer indicates the intensity of heat, and may be employed in medical practice to determine the heat of the body, and to ascertain the variations, if any exist, between the several parts. For the latter purposes the "surface thermometer" and the thermo-electric pile should be employed. The former, because of its size, facility of use, and comparatively low price, must continue to be used chiefly. For nice investigations, to detect minute differences in temperature, there is no question of the superiority of the latter. As it has been brought forward recently as a method of physiological research, and has been utilized in medical diagnosis, it seems desirable in this work to devote some little attention to these several points.

The natural variations in the temperature of the body in different situations, at different hours of the day, and under the influence of various disturbing causes, have been investigated with more or less success since thermometry came into general use, but it was not until the thermo-multiplier was employed for this purpose that nice discriminations became possible. Acting on the suggestion of Lombard, and employing his thermo-electric apparatus, Hammond was the first to distinctly establish the fact, that the left side of the brain is, in the normal condition, higher in temperature than the right. It would be a distinct digression from the proper subject of this work to include the results obtained by observa-

tions with thermometers made by Broca, Dr. L. C. Gray, of Brooklin, Prof. Schiff, Prof. Paul Bert, Dr. Amidon, of New York, and others, and I, therefore, pass them over. "In 1866 Dr. Lombard commenced a series of experiments with thermo-electric apparatus, on the temperature of the human head in the quiescent mental condition, and in the states of intellectual and emotional activity. These experiments showed that the exercise of the higher intellectual faculties, as well as the different emotions, caused a rise of temperature in the head, perceptible through the medium of delicate apparatus. Merely arousing the attention could produce the same result."[1] Lombard has published a large number of observations which seem to prove his postulate. Although not strictly included in the sphere of this chapter, I may so far digress as to state that these results, obtained with so much care and faithful work, are, after all, vitiated by the fact that the temperature of the scalp may vary greatly under circumstances of mere motor activity. Thus, Dr. Amidon, of New York, apparently proved that the action of groups of muscles caused a rise of temperature in the motor centres of the cerebral cortex, demonstrated, he maintained, by a special elevation of the heat of the scalp overlying the supposed region. Thus working the arm violently for some minutes, it was ascertained that the temperature of the motor centre of the opposite hemisphere was raised above the ordinary level. It seems clear, however, that the surface of the body is liable to great fluctuations of temperature, and that the changes supposed to occur in the brain go no deeper than the scalp. When, however, inflammatory action occurs in the thoracic and abdominal organs, the

[1] Experimental Researches on the Regional Temperature of the Head, by J. S. Lombard, M.D. London, H. K. Lewis, 1879.

walls of the cavity corresponding to the position of the inflamed organ may be warmer than the symmetrical region on the healthy side. A good many observations have been made on this point, and the fact of such rise of temperature seems conclusively established. To determine these variations under all circumstances is an important work for future investigators. Hence, it follows that the thermo-electric pile, the most sensitive of all means for determining minute variations in temperature must come into more general use for the purposes above indicated.

APPENDIX.

BATTERY FLUID.

DISSOLVE (1) an ounce (avoirdupois) of bichromate of potassium, in eighteen (18) fluidounces of hot water in an earthenware vessel. Allow it to cool to the temperature of the air, and *when cold* add two (2) fluidounces of sulphuric, and a quarter of an ounce (2 drachms) of nitric acid. The solution should not be used until cold. It is better therefore to keep it on hand.

HOW TO AMALGAMATE THE ZINCS.

The zincs should be first cleansed by washing them with dilute sulphuric acid (1 part of the acid to 12 parts of water). Prepare in a vessel of sufficient size a solution of the acid just given. Put into the vessel some mercury, say a tablespoonful. Then lower the zinc in the acid solution, to the mercury, and rub the surface of the zinc with some mercury until it assumes a brilliant silvery hue. The following solution may be used to accomplish the same object.

"Mix half a pound (8 oz.) of nitric with one pound of muriatic acid, to which add four ounces of mercury. When the mercury is dissolved, add a pound and a half more of muriatic acid." Immerse the zincs in this solution *for a few seconds*, then quickly remove to a vessel of clean water and rub them with a cloth or brush, when they will be found covered with amalgam.

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